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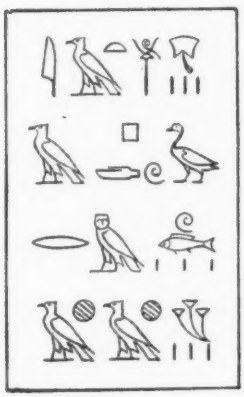

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THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 8 OCTOBER, 1944 NUMBER 4

STATUS OF EELGRASS IN MASSACHUSETTS[1] DURING 1943

C. E. Addy and David A. Aylward

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The nearly complete disappearance of eelgrass (*Zostera marina*) along the Atlantic coasts of both Europe and North America during 1931 and 1932 provoked widespread anxiety among conservationists because of the possible devastating effect on many forms of coastal wildlife. Under normal conditions, eelgrass was by far the most abundant plant species in brackish-water bays and creeks from North Carolina to southern Labrador. The sudden disappearance of the plant therefore altered the whole ecology of waters within its normal range.

This catastrophe of nature not only affected man's industrial interests, but also influenced the shellfish, waterfowl, and other wildlife which depend directly or indirectly upon the plant. Many thousands of tons of eelgrass formerly were harvested annually for such varied uses as fuel, bedding, fertilizer, packing, and upholstering. More recently it has been used extensively as insulation against cold, heat, and sound. According to Cottam (1934), the dried material originally was sold for $20.00 to $30.00 per ton delivered to factories.

[1] Since this article was submitted, the eelgrass along the Massachusetts coast has shown widespread blackening and degeneration characteristic of the disease. The effects on the health and survival of the present beds are being investigated.

Of its value to waterfowl and other wildlife, Cottam (1934) wrote, "However great the value of eelgrass for economic purposes, this is probably much less than its value in nature. As the dominant plant along much of the coast, it bears an important relation to every creature living in these waters, and thus is also of indirect value to man. It is normally the staple winter food (more than 80%) of sea brant, an important food of Canada geese and black ducks, and it is only slightly less important to scaups, redheads, and other waterfowl feeding along coastal waters. The numbers of brant, already seriously reduced by hunting, are so greatly menaced by this curtailment of their natural food supply that the Department of Agriculture has declared a closed season for them in the Atlantic Coast States. Disappearance of eelgrass is also affecting the fishery and shell-fishery industries and has resulted in such erosion of many coastal areas as to alter considerably their surface features."

Numerous theories have been advanced as to the probable cause for rapid disappearance of *Zostera*. Various bacteria and fungi are associated with the disease, and the mechanical effect of storms and those of pollution and extreme heat have been advanced as causes, at least locally. Drought and excess precipitation and the subsequent

alteration of salinity have been suggested as possible factors but subsequent investigations did not support these assumptions. Various investigators in Canada, the British Isles, European and Asiatic countries, and the United States have undertaken local studies of the diseased plants. In the United States, Renn (1936) demonstrated the presence of an amoeba-like *Labyrinthula* parasitic in the leaves of the plant over the entire range of the epidemic condition. Experimental inoculation of healthy leaves with *Labyrinthula* produced the discoloration and streaking characteristic of the disease. Likewise "the rapidity with which it produces infection in these experiments is commensural with the aggressive habit of the disease in nature, and in this respect it seems to be the only organism transferred in a time interval comparable with the severity of the disease." Specimens of leaves collected in December 1943 from thriving beds of eelgrass at Newburyport, Massachusetts, were demonstrated by Renn to contain active *Labyrinthula.*

Cottam (1934) stated that eelgrass has fluctuated in abundance from time to time in various localities but never to the devastating proportions of 1931 and 1932, when over 99 per cent of that along the Atlantic Coast is believed to have been destroyed. Subsequent local successes in recovery have been reported, only to find the plants gone the following year. During the past four years, however, there has been a rather consistent return at several points along the Massachusetts Coast.

PRESENT DISTRIBUTION

The Massachusetts Department of Conservation in 1943 undertook a limited reconnaissance of coastal waters to determine the status of eelgrass as part of a general state-wide waterfowl program, supported by Federal Aid to Wildlife funds. No personnel was available exclusively to make a complete and detailed study, but the authors attempted to gather data incidental to their other duties. The extent of recovery and the utilization of eelgrass by waterfowl were studied, and preliminary experiments made on transplanting and storing the seed. In this work, coastal wardens of the Division of Marine Fisheries cooperated with reports on the location and size of beds in their respective districts.

Eelgrass is returning at many places along the Massachusetts coast and on adjacent islands. At no place is it as abundant as before 1930, but in some places the recovery is so remarkable that the plant again may be exerting a favorable influence on waterfowl. In Figure 1[2] the relative abundance is shown and roughly estimated, but the map gives no indication of the actual size of beds. A luxuriant area of several acres in Newburyport Harbor and the Ipswich River is shown as "abundant" and the same sign is used for a growth in Cape Cod Bay of well over 100 acres. Moderate scattered growths, in small patches, may involve considerable differences in actual area covered by beds.

Sizeable areas of eelgrass in bays and sounds may be easily overlooked, even when the area apparently is well surveyed in a boat. The depth and turbidity of water, wind, light, growth of

[2] Since this article was submitted a moderate growth of eelgrass has been reported in Sengekontacket pond on Martha's vineyard.

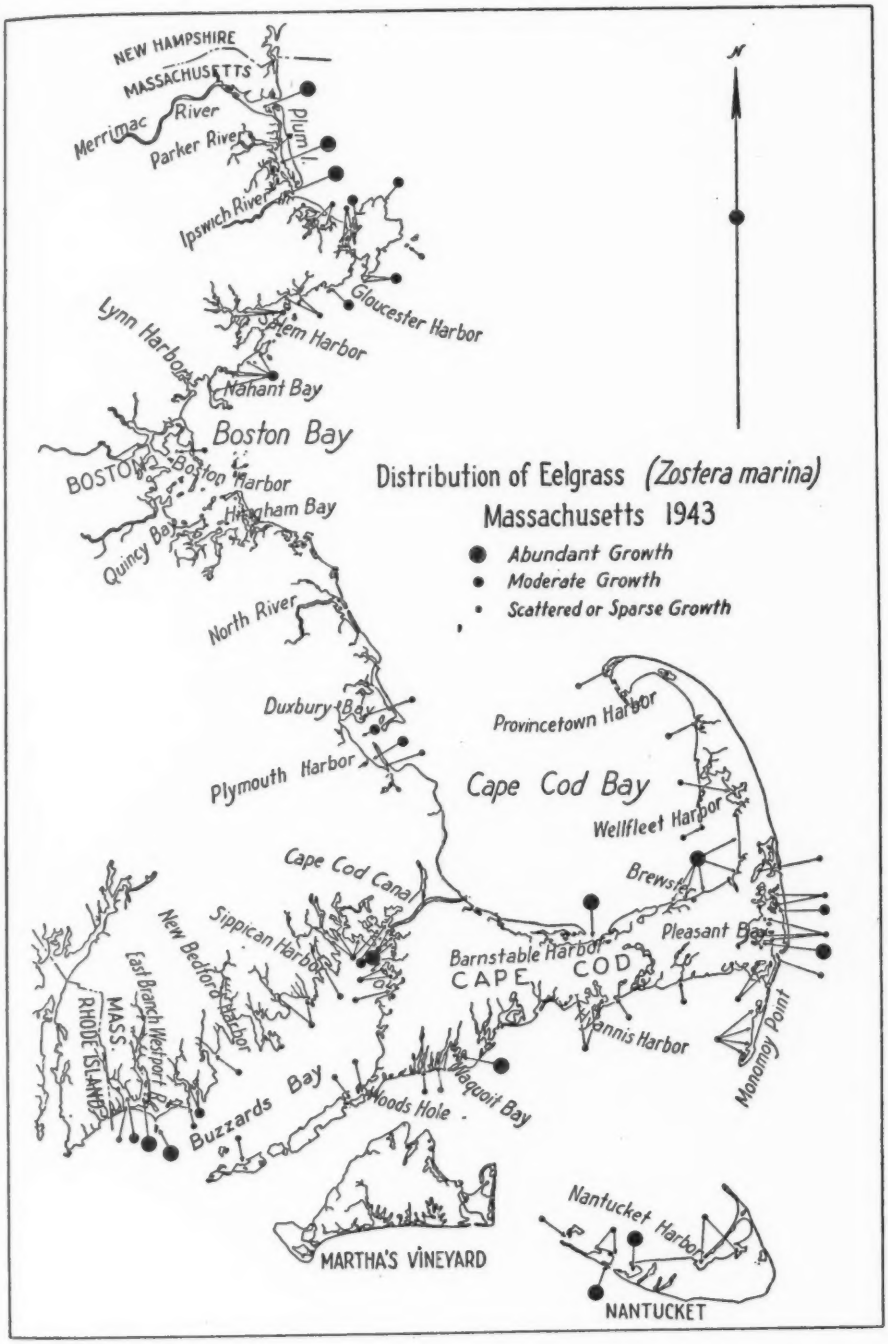

Fig. 1. Distribution of Eelgrass (*Zostera marina*) in Massachusetts, 1943.

the plants, and ability of the observer are all involved. It may be safely assumed, therefore, that eelgrass, in varying amounts, occurs in areas not here reported.

GROWTH AND REPRODUCTION

Setchell (1922, 1929) provides a detailed description of the growth and reproduction of eelgrass, and its life history in Massachusetts coastal waters seems mainly to follow that account. The upright fruiting stems, however, develop secondary plants late in the season after seed production has terminated, and some of these new growths develop roots, but it is unknown whether such reproduction contributes significantly to spread of the species.

Setchell gives considerable space to a theory that seed production is governed strictly by the five degree temperature interval between 15° and 20°C., stating also that temperatures above 20°C. produce a "blasting" of the flower parts and the plants enter into a "heat rigor" period. From his discussion, we infer that the temperature data were taken when various specimens were collected by him and cooperators, and probably refer mainly to the Pacific Coast form (*Zostera marina* var. *latifolia*), but Setchell applies the data likewise to the Atlantic Coast form (var. *typica*).

On tidal areas supporting eelgrass, single readings are not reliable because the temperatures are influenced by the tide, depth of water, location of plant beds, weather, and time of day. In Newburyport Harbor and the Ipswich River, flowering and fruiting were heavy where the relatively cold sea water (14°–15°C.) reached for only a short period of the day or possibly only during the higher tides. On eelgrass beds a mile or more upstream in the Ipswich River, water temperatures of 24° and 25°C. were recorded in late July and the average daily temperature probably is above 20°C. during the summer. At Newburyport temperatures from 17° to 26°C. were recorded over eelgrass beds during the summer, and in Cape Cod Bay the temperatures were 18.5° to 25°C. on August 12 and 13.

Heavy flowering and fruiting occurred in 1943 at Newburyport Harbor, Ipswich River, Barnstable Harbor, and to some extent in Cape Cod Bay. Seedling growth also was abundant at these places. Temperature data for these localities are far from complete, but indicate that flowering and fruiting (Pl. 15) proceed uninterrupted at temperatures substantially (24°–25°C.) above 20°C. during July and August. Flowering was first seen at Newburyport on June 19. Through July and August, flowering and fruiting were at their height and gradually declined in September and October. Many detached dead leaves and upright stems were observed during late July and to some extent in August, but there apparently was no wholesale breaking away of the upright fruiting stems because many secondary root-forming plants developed, as mentioned previously.

WATERFOWL AND EELGRASS

The eelgrass in a few localities has returned sufficiently to attract waterfowl, particularly brant and Canada geese. In Cape Cod Bay, off Brewster and East Brewster, the extensive stands apparently were a major factor in holding a winter population of about 2,000 geese and over 100 brant. Residents claimed that the geese fed on the "flats" all

Eelgrass (*Zostera marina*). Photographs by David A. Aylward. *Above.* Plants showing pistils and stamens; insert shows seed after removal from spathe. *Below.* Healthy growth associated with mussels (*Mytilus edulis*) in Newburyport Harbor, Massachusetts, at low tide.

winter (1943–44), whereas before the eelgrass returned Canada geese were rare during the winter at those points. On January 15 and 16, 1944, several hours were spent watching groups of geese at close range and with binoculars; so far as could be determined, their diet was almost entirely of eelgrass. Examination of feeding areas showed considerable floatage of torn and broken parts of leaves and roots of eelgrass. Droppings at almost any place on the "flats" seemed to be almost entirely of eelgrass remains. With the geese were 120 brant, also feeding on eelgrass. Black ducks were abundant over the beds but whether they partook extensively of eelgrass is unknown. They are known to feed extensively on animal life associated with the eelgrass.

For most of the winter, flocks of 12 to 30 Canada geese were in the Newburyport Harbor area, and invariably over eelgrass beds. On several occasions they were watched at close range, and appeared to be feeding on all parts of the plants including roots and leaves. Roots and tender new growths of *Spartina alterniflora* also are utilized extensively by these birds at Newburyport. As at Cape Cod, large numbers of black ducks fed in eelgrass beds at Newburyport during the winter. No black ducks were collected, hence it is not known whether the plant forms any significant percentage of their food.

The blue mussel (*Mytilus edulis*) is perhaps the most common shellfish in *Zostera* beds. Mussels frequently are abundant on the mud bottom of eelgrass patches and mussel spat on the leaves sometimes literally covers sizeable areas of eelgrass during the summer. As the spat develops, the plants become flattened down from the weight of the mollusks. Other mollusks observed in lesser quantities were the horse mussel (*Modiolus demissus*), common scallop (*Pecten irradians*), long-necked clam (*Mya arenaria*), bent-nosed clam (*Macoma balthica*), and periwinkles (*Littorina* spp.).

Crustaceans such as scuds (Amphipoda) and the common prawn or shrimp (*Palaemonetes vulgaris*) are abundant in patches of eelgrass. Several small unidentified species of crabs occasionally are observed in eelgrass stands. According to Cottam (letter) eelgrass also offers protection for schools of fishes.

During the summer, considerable eelgrass was coated, especially on the distal portion of the leaves, with a brown filamentous growth; microscopic examination showed this to consist of chains of navicular-like diatoms. In Cape Cod Bay sizeable areas of eelgrass were found coated with a white calcareous substance which C. E. Renn identified as a growth of hydroids.

TRANSPLANTING EXPERIMENTS

During May and June, transplants were made from beds in Newburyport Harbor to sites in adjacent creeks. At low tide, clumps of eelgrass and soil were dug with shovels, placed in the bottom of a skiff, and then the loaded boat was towed to another area where the plants were set out. Transplants were made on the same tide wherever conditions warranted. Plantings of 12 to 15 clumps each were made at four places in or near the northern entrance of Plum Island River, and at four others in Lost River which empties into Plum Island River. Another series was made in Lost River during August.

These transplants appear to have done well on proper sites. The best results were on soft to moderately firm sandy mud, exposed little or not at all during low tides. Mucky bottoms and areas exposed for an hour or more at low tide yielded poorly. Some of the better transplants produced seed and increased from four to five times in area by early autumn, the most pronounced growth being in August. The first plantings in Lost River failed, probably because of the mucky bottom and exposed site. One planting in Plum Island River was completely eradicated by a brood of geese by mid-July.

In late August plants free of soil were transplanted to Plum Island River and apparently were well when last checked before cold weather. Success in transplanting without the inclusion of soil would greatly reduce the cost of operation.

During August eelgrass seed and plants were harvested for immediate planting and also for storage during the winter. Attempts to collect seed by stretching a fine-meshed seine around the down-stream portion of seeding beds and then agitating the plants yielded little seed. It was found more practical to pull up whole fruiting stems by hand.

The ripened seeds are borne in spathes which float when released, necessitating hand planting. Success by this method and by sowing seed removed from the spadix has not been demonstrated. It is hoped that such experimental plantings made in the autumn will produce results in the spring. When freed from the spathes, the seeds sink rapidly and normally lodge in mussel beds or other irregular surfaces.

Experimental plots were marked off near the mouth of Plum Island River in which seeds were planted by sowing and by hand planting the individual spathes. These were in mussel beds and on soft sandy mud free of mussels, but no growths were noted before cold weather began.

Various methods are being tried to store the seeds and plants for spring planting. Shallow boxes about 12×18×3 inches, with screen wire tops, and containing seeds and plants were anchored on the bottom in a protected location in Plum Island River. Spathes containing seeds were stored loose and between layers of sand. One box of whole plants also was anchored on the river bottom.

One box of spathes between layers of wet sand was stored at 12° F. in a refrigerator; two more with spathes between layers of wet sand and also loose were stored at 32° to 40°F. Approximately a half bushel of roots and whole plants also were stored under these conditions. A portion of these stored seeds are to be planted and the remainder held for another year or more in cold storage.

Shortly after loss of the *Zostera* beds on the Atlantic Coast, attempts were made by various persons to introduce the Pacific form (var. *latifolia*), then apparently unaffected by the disease. So nearly as can be determined, these transplantings survived for only a year or two at the most. Moffitt and Cottam (1941) reported that the disease subsequently was found at various points along the Pacific Coast and some beds were reduced to 25 or 40 per cent of normal. Examination by Renn of preserved material from such infected beds revealed *Labyrinthula*.

SUMMARY

Eelgrass is returning in substantial amounts at many points along the Massachusetts coast and has steadily increased during the past four years but is not as abundant anywhere as before 1930. It is premature to consider the species as definitely on the road to complete recovery. *Labyrinthula*, the organism closely associated with the wasting disease, is still present.

Heavy flowering and fruiting occurred in various eelgrass beds during 1943. Few water temperatures were recorded, but there is reason to believe that reproduction continues at temperatures substantially higher than 20°C. Flowering was first observed on June 19. Flowering and fruiting were highest throughout July and August, then gradually declined during September and October.

Canada geese, sea brant, and black ducks have been observed on eelgrass beds, and the geese and brant fed almost entirely on eelgrass. The sizeable patches of *Zostera* on Cape Cod are believed to have contributed materially to keeping geese and brant there during the winter.

Success was achieved in transplanting eelgrass by removing soil with the roots. Soft to moderately firm sandy mud, exposed little or none during low tides, yielded the best results. Mucky bottoms and areas exposed for an hour or more produced poorly. Late planting of eelgrass without the inclusion of soil showed possibilities of success, but no definite conclusions can be stated.

Seeds and roots were harvested for storage and immediate planting but the experiments are preliminary and incomplete.

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MUTUAL INTERESTS OF WILDLIFE CONSERVATION AND MALARIA CONTROL ON IMPOUNDED WATERS[1]

A. H. Wiebe and A. D. Hess

Tennessee Valley Authority: Norris, Tennessee, and Wilson Dam, Alabama

For some years there has been considerable controversy between mosquito control and wildlife conservation interests, and it has been the opinion of some persons that these interests were entirely incompatible. This conflict came to attention early in the development of programs for malaria control and wildlife conservation by the Tennessee Valley Authority at reservoirs on the

[1] Published by permission of the Tennessee Valley Authority. Joint contribution from Departments of Forestry Relations and Health and Safety.

Tennessee River and its tributaries. Control of the malaria mosquito (*Anopheles quadrimaculatus*) is the principal basis for the malaria control program. In July 1935, a committee was formed to coordinate the control of mosquitoes with the development of wildlife and fisheries in the Tennessee Valley. Later, the U. S. Bureau of Fisheries and U. S. Biological Survey became interested in the relation of malaria control to wildlife conservation in the Valley, particularly on the 40,000-acre wildlife refuge established on Wheeler Reservoir.

On February 28, 1939, a meeting was held in Knoxville, Tennessee, attended by representatives of the U. S. Biological Survey, U. S. Public Health Service, U. S. Bureau of Fisheries, U. S. Bureau of Entomology and Plant Quarantine, and the Forestry Relations and Health and Safety departments of the Authority. This led to cooperative investigations on the relation between mosquito control and wildlife conservation during the summers of 1939 and 1940; the results have been summarized previously by Bishop (1940) and Hinman *et al.* (1941). Most importantly there resulted a better understanding between the groups interested in these two subjects. At a joint meeting of the Policy and Technical Committees at Knoxville on September 6, 1940, it was agreed that "since a working relationship now exists whereby a study of these problems may be continued as a part of the regular research programs of the interested agencies, the formal organization should be discontinued."

Since 1940, informal voluntary cooperation has resulted in an increasingly better understanding of the relationships of wildlife conservation and malaria control on impounded waters. Further information has shown that, at least in the Tennessee Valley, the two subjects have mutual interests far outweighing, in both number and importance, any antagonistic features. The results of wholehearted cooperation and of scientific approach have been much more favorable than anticipated by even the most optimistic at the beginning.

Most conservationists associate mosquito control with drainage and the destruction of aquatic and marsh habitats but, in the Tennessee Valley, just the opposite has taken place; the reservoirs have created many thousands of acres of new aquatic habitat. It would be expected, therefore, that malaria control and wildlife conservation in such a situation might differ from the conventional relationships. The present paper is intended to show some of these mutual relationships in the hope of a better and more widespread understanding of the two related interests on impounded waters.

The malaria control program on these reservoirs conforms to regulations of the health departments of the several states involved and to approved practices in the southeastern states. It involves species sanitation against *Anopheles quadrimaculatus*, the only important local vector of malaria. The program is coordinated with other interests of the Authority such as flood control, navigation, and generation of hydroelectric power, as well as with conservation interests, and is being developed and improved by a research staff. Results are made available to the malaria control specialists of the Army, Navy, U. S. Public Health Service, Rockefeller Foun-

dation, various universities, and other agencies outside of the Authority. The final planning, technical supervision, and appraisal rests with a "malaria control team" consisting of a malaria control engineer, a medical malariologist, and a biologist. The coordination of malaria control and wildlife conservation interests is carried out through the Biological Readjustment Division of the Forestry Relations Department which is responsible for the program of wildlife conservation and fisheries management on the Authority's reservoirs.

The main phases of the current malaria control program are reservoir preparation, shoreline maintenance, water level management, larvicidal applications, and permanent shoreline improvement. Constant effort is made to develop naturalistic control measures such as water level management in preference to artificial means such as the application of larvicides.

Reservoir Preparation

The malaria control program at each reservoir involves clearing of sites in accordance with detailed specifications before impoundage. The U. S. Bureau of Fisheries has also recommended such clearing to prevent injurious effects upon the fish population. In much of the zone of water level fluctuation low-stumping operations have been applied to facilitate shoreline maintenance work for malaria control after impoundage. These areas have proved useful in fisheries management investigations since they make seining possible in the study of fish populations after impoundment. Hence, the Biological Readjustment Division uses maps showing the low-stumped areas in reservoirs recently prepared for impoundment.

In addition to such clearing, specifications for reservoir preparation provide for marginal drainage to connect depressions such as limesinks with the main reservoir. This insures that marginal depressions can be subjected to water level management along with the main reservoir and provides access for boats in carrying on mosquito control operations. Marginal drainage also is beneficial to the fisheries management program since it prevents the stranding of fish in isolated pools when the water level is lowered.

Shoreline Maintenance

After impounding water in a reservoir, the Authority carries out a program of shoreline maintenance for malaria control in which several mutual interests with wildlife conservation have recently come to light. One important phase is the annual conditioning of the shoreline in the autumn and winter. The annual growth of vegetation in the zone of fluctuation is removed by area burning, mowing, or hand labor. The maximum benefits for malaria control derive from the control of water tolerant woody species such as black willow, buttonball, green ash, and trumpet vine. Control of these woody species also appears to be the dominant factor in maintaining the production of wildlife food plants in the zone of fluctuation. If shoreline conditioning is omitted, this zone will produce dense stands of willows or other water tolerant woody species that shade out and prevent the production of wildlife food plants; however, when these woody species are so controlled, the zone will be occupied by dense stands of herbaceous species,

commonly rice cutgrass (*Leersia oryzoides*), wild millet (*Echinochloa crusgalli*), smartweeds (*Persicaria pennsylvanica*, *P. lapathifolia*, and others), chufa (*Cyperus esculentus*), and other nut grasses (*Cyperus erythrorhizos*, etc.). Since these species do not germinate until they are dewatered, they "follow water level recession" rather than invading the water, which minimizes their importance for malaria control. Studies by Bellrose and Anderson (1943) in Illinois indicate that these plants are excellent sources of duck food. Thus, a routine malaria control operation plays a major role in maintaining a supply of wildlife food plants around the margins of a reservoir. Conservationists have pointed out that the ecological succession in an area after impoundment often tends to be of a type unfavorable to wildlife. In the reservoirs of the Tennessee Valley Authority, this unfavorable succession evidently is prevented by the annual shoreline conditioning for malaria control which holds the vegetation of the zone of fluctuation in those initial stages of plant succession more favorable for wildlife. Area burning, where possible, is the most economical means for removing the annual growth and has proved effective in controlling coppice of willow and other water tolerant woody species. Such measures might be applied purely for the purpose of wildlife conservation in some areas where there is no annual shoreline conditioning for malaria control.

In addition to shoreline conditioning, the Authority controls aquatic growth to prevent the production of malaria mosquitoes. The chief plants involved are alligator weed (*Achyranthes philoxeroides*), lotus (*Nelumbo lutea*), cattail (*Typha latifolia*), and giant cutgrass (*Zizaniopsis miliacea*). These are also considered undesirable as waterfowl food plants (Martin and Uhler, 1939). Their eradication or control is desirable therefore in the interests of both wildlife conservation and malaria control. As an example of this mutual interest, information accumulated by the Health and Safety Department on means for controlling lotus has been used by the U. S. Fish and Wildlife Service in developing methods for control of this species in Reelfoot Lake in northwestern Tennessee. Other species undesirable for either wildlife conservation or malaria control but not now present in the reservoirs of the Authority include the water chestnut (*Trapa natans*) and water hyacinth (*Eichornia crassipes*). Both groups are interested in preventing these and similar species from being introduced into the Authority's reservoirs where they might create serious problems for both malaria control and wildlife conservation.

Observations on marginal plants indicate that some species least obnoxious in malaria control are desirable for wildlife conservation. The water shield (*Brasenia schreberi*) appears to have properties or to create conditions inimical to production of *Anopheles quadrimaculatus*. Of all macroscopic plants studied in the Tennessee Valley, this is the only species in which practically no breeding of malaria mosquitoes has been found; similar observations have been made elsewhere. The water shield is a valuable wildlife food plant, hence its establishment and maintenance in suitable limited areas will serve jointly in malaria control and wildlife con-

servation. The squarestem spikerush (*Eleocharis quadrangulata*) is classed as a valuable wildlife food plant and is not very obnoxious from the standpoint of malaria control. Its dense emergent stems evidently serve as a mechanical barrier to oviposition by *Anopheles quadrimaculatus* (Rozeboom and Hess, 1943), and breeding therefore is limited to light growths, to the margins of stands, and to places where the stems have been broken over in the water. Experiments show this plant is tolerant to fluctuation and drawdown of water level and it might be effectively fitted into existing plant associations at certain contours so as not to add materially to the malaria control problem (Hinman *et al.*, 1941).

WATER LEVEL MANAGEMENT

Regulation of water levels has been used in the Southeastern States for over a quarter of a century for malaria control. Since its beginning, the Tennessee Valley Authority has used this naturalistic measure to control the production of *Anopheles quadrimaculatus*, and considerable improvements have been developed. Formerly this method was referred to commonly as "water level fluctuation" but more recently has been termed "water level management" because the schedule includes a constant pool phase of equal or greater importance than the fluctuation phase. The water level management schedules currently recommended for the Authority's reservoirs have been discussed in detail by Hess and Kiker (1943). On the main river reservoirs these comprise four separate phases: (1) An early spring flood surcharge to strand the winter accumulation of drift and flotage; (2) a relatively constant normal maximum pool level during the early spring growth period (April 1 to May 15–31) to hold back invasion by marginal vegetation and to aid in control of willows and other water tolerant woody species; (3) weekly cyclical fluctuations (amplitude 12 inches) without recession until the beginning of heavy breeding by *Anopheles quadrimaculatus* (about July 1); and (4) the combined use of cyclical fluctuation and seasonal recession during maximum production of *A. quadrimaculatus* (July to September).

The flood surcharge phase has no important relation to wildlife conservation, but may help to provide resting grounds for waterfowl during the northward spring migration.

The constant pool level phase has an important relation to the Authority's fisheries management program. Inclusion of this phase is possible because extensive production of *A. quadrimaculatus* (which creates the need for water level fluctuation) does not usually begin in the lower reservoirs until June and in the upper reservoirs until July. The spawning period of bass and other centrarchid fish coincides with the period for the constant pool phase, and the maintenance of relatively constant pool levels during this period therefore provides good spawning places for these fishes, ensuring that their eggs will not be dewatered before hatching. There is also a heavy production of plankton organisms during the constant pool level phase; this provides food for the young fish and gives them a good start in growth before the beginning of water level recession. A good crop of fish therefore accompanies the use of the constant pool phase and this measure is

highly beneficial both from the standpoint of malaria control and fisheries management.

Inclusion of the constant pool level phase permits reduction in use of the third and fourth phases—cyclical fluctuation and seasonal recession. From the malaria control standpoint, it is particularly desirable to limit seasonal recession to the minimum amount required for current control of *Anopheles quadrimaculatus*. Any further recession brings no increased benefits in control of mosquito larvae and results in extending the zone of marginal growth invasion and therefore increases the cost of annual shoreline conditioning. In one reservoir, Lake Wilson, which has a relatively high generating capacity but low storage, it proved possible to obtain effective control of *Anopheles quadrimaculatus* by use of cyclical fluctuation alone without seasonal recession. With the present program on the other main river reservoirs, a satisfactory schedule of water level management for malaria control can be obtained with a seasonal recession of approximately two feet where the other phases (flood surcharge, relatively constant pool, and cyclical fluctuation) are adequately provided. There are exceptions to the rule but, in general, it appears that the less the fluctuation, the greater will be the wildlife values (Gabrielson, 1941). Martin and Uhler (1939) state that "no single factor is more important in preventing the development of waterfowl feeding grounds than extreme or irregular fluctuations in the water level." Unregulated fluctuations in water level, therefore, are of mutual concern to the malaria control and wildlife programs.

The over-all schedule of water level management for malaria control often favors certain wildlife food plants such as wild millet (*Echinochloa crus-galli*) and rice cutgrass (*Leersia oryzoides*). They thrive particularly well in soils submerged during the early part of the growing season but exposed later, in the summer and autumn (Martin and Uhler, 1939), thus being well adapted to the type of water level schedule used for malaria control.

LARVICIDAL CONTROL

For a number of years the Authority has been developing the use of naturalistic malaria control measures, such as water level management, to minimize the need for artificial larvicidal measures. The latter are more temporary and more expensive than the more permanent and effective naturalistic measures; hence they should be used only where other measures do not provide the necessary control. In certain areas it has been possible to decrease the use of larvicides by the mosquito-proofing of houses. The use of larvicides, particularly oils, is objectionable from the standpoint of wildlife conservation. In the cooperative studies during 1939, routine airplane dusting with Paris green showed no deleterious effect upon vegetation and caused no extensive destruction of aquatic organisms important as fish food; larvicidal oil, however, proved toxic to vegetation when applied in excessive quantities and dedestroyed amphipods in addition to mosquito larvae, although mayflies, dragonflies, and other aquatic organisms did not appear to be affected.

Oiling is the most expensive larvicidal control for *Anopheles quadrimaculatus* and current reductions in the use of

larvicides are aimed particularly at reduction in costs. It is evident, therefore, that a decrease in larvicidal control, particularly oiling, is desirable from the standpoints of both malaria control and wildlife conservation. Current research is endeavoring to discover anopheline larvicides more satisfactory than either Paris green or oils.

PERMANENT SHORELINE IMPROVEMENT

The obvious desirability of more permanent measures rather than those of purely temporary nature has led the Authority to undertake permanent shoreline improvement for malaria control. This includes diking and dewatering, cutting and filling, and restriction of land use to daytime occupancy. On recent projects, such as the Kentucky Reservoir, the permanent shoreline improvement program has been incorporated into the pre-impoundage preparation of the reservoir. On older projects, such as Wheeler Reservoir, this was developed after impoundage.

Diking and dewatering offer particular promise as means to benefit both malaria control and wildlife conservation. Large backwater areas that offer maximum difficulties for malaria control are diked off from a main reservoir and pumps are installed to pump water either into or out of the area. During the summer breeding season of *Anopheles quadrimaculatus*, the areas are kept dewatered to eliminate production of malaria mosquitoes and to remove the need for control of marginal and aquatic growths. During this period, wildlife food species are planted in the area. In the autumn, when mosquito breeding has ended and waterfowl begin to migrate southward, the areas are reflooded to serve as feeding and resting grounds for the birds. This is particularly desirable because the reservoirs then are generally drawn down for power and flood control needs; without the dikes, the most valuable backwater areas would be dewatered and made unavailable for use by aquatic feeding waterfowl. The value of these areas as waterfowl feeding grounds depends as much upon the water as upon the food plants; being diked off and flooded during the autumn and winter they meet a real need in the wildlife conservation program. An example of this type of project is the diking and dewatering area of Buckeye-Blackwell Swamp on Wheeler Reservoir. Although wartime restrictions have prevented the installation of pumping units there, the swamp served a useful function during the 1943 season. Power and flood control demands on the water stored in Wheeler Reservoir during the autumn of 1943 drew the water down 5 or 6 feet below normal pool level which dewatered most of the backwater feeding areas on the Wheeler National Wildlife Refuge; however, the gates were closed on the Buckeye-Blackwell area and natural inflow maintained the water level there. As a result, waterfowl unable to find suitable resting places elsewhere made extensive use of this area and thousands were seen in an airplane flight. Diking and dewatering projects apparently will be increasingly important for both malaria control and wildlife conservation.

Another permanent measure in malaria control has been to restrict land use within a one-mile zone of the reservoir to daytime occupancy. Since the ma-

laria vector (*Anopheles quadrimaculatus*) bites only at night, such limitation will prevent the transmission of malaria. Extensive use of such limitation in occupancy had been made at Kentucky Reservoir, the largest and newest project, scheduled for impoundage during 1944. Where the best over-all land use is served by removal of human populations from certain wildlife areas or refuges, both malaria control and wildlife conservation are helped. An example of this sort is in the Kentucky Woodland Wildlife Area in the lower end of Kentucky Reservoir.

BIOLOGICAL CONTROL

The Authority has been investigating various types of biological control in keeping with its policy to increase the use of naturalistic measures and to decrease those of an artificial character. The Departments of Forestry Relations and of Health and Safety have made detailed studies on the feeding of top minnows (*Gambusia*) on the larvae of malaria mosquitoes (Hess and Tarzwell, 1942). There has resulted a better understanding of the role of *Gambusia* in the control of *Anopheles quadrimaculatus* and of the possibilities for increasing its effectiveness. Maintaining normal maximum pool levels during the spring favors the production of *Gambusia*, as well as of game fishes, and probably yields increased numbers of this species. Although the reduction of *Anopheles quadrimaculatus* by the top minnow and other natural control factors does not appear to be sufficient for malaria control purposes in problem areas, this fish is important in helping to limit the production of the mosquitoes. *Gambusia* seems to be particularly important in connection with the use of water level fluctuation where, during recessions, the mosquito larvae are forced from the protection of marginal vegetation and exposed to increased predation by *Gambusia*. This latter factor contributes much to the effectiveness of water level fluctuation in controlling *Anopheles quadrimaculatus*.

Gambusia also serves importantly as a forage fish for bass and other game and pan species. Information leading to increased production of *Gambusia* therefore is desirable for both malaria control and wildlife conservation. Biologists of the TVA are experimenting with the introduction of several exotic species of top minnows which may serve as forage fish and help in mosquito control; after the war species from other parts of the world will be considered. The introduction of *Gambusia* into certain areas of Europe where it is free from its natural enemies has proved effective in the control of malaria mosquitoes and similar success might result with exotic species in this country.

STREAM SANITATION

Programs for wildlife conservation and for human health and safety have a mutual interest in combating stream pollution or, stated affirmatively, in stream sanitation. Unrestricted pollution of streams and reservoirs inevitably would have an adverse effect upon public health as well as upon the production of game and fish. The Tennessee River is one of the few major streams in this country still relatively free from pollution. Many persons hope to maintain the river in this condition despite the increased industrialization which ac-

companies the development of hydroelectric power. High among the regional interests of the TVA is that of keeping the Tennessee Valley healthful for rest and recreation as well as for work.

The foregoing discussion has been devoted entirely to considering matters common to wildlife and malaria control. This approach was deliberate, because earlier discussions of the relationships between the two have emphasized points of conflict. The authors realize that the interests of malaria control and wildlife do not always lie parallel. They feel, however, that these two programs have much in common in the Tennessee Valley and that many of the past conflicts have resulted from failure to appreciate their mutual interests. Differences of opinion resulted also in part because wildlife workers failed to assess properly the effect upon wildlife of different operating programs.

SUMMARY

The experiences of the Tennessee Valley Authority during the past five years on the relations between malaria control and wildlife conservation on impounded waters indicate that many of the conflicts between these two interests are apparent rather than real; actually the two fields have several mutual interests. The following malaria control operations are also beneficial to wildlife conservation: reservoir clearance, marginal drainage, annual shoreline conditioning, control of aquatic plants such as lotus, use of constant pool levels and minimized seasonal recession in schedules for management of water levels, establishment of diking and dewatering areas, restricting human populations on some areas, minimizing the use of larvicides, and promoting biological methods for the control of *Anopheles quadrimaculatus*. Wildlife conservation also has mutual interests with the over-all health program such as the control of stream pollution.

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PROTEIN REQUIREMENTS OF BREEDING BOBWHITE QUAIL

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A level of dietary protein as low as 12 to 13 per cent will promote satisfactory egg production in chickens, but according to Titus (U. S. Dept. Agric., Yearbook, 1939: 787–818) production, especially among pullets, tends to increase as the protein content is raised from 13 to 20 per cent. Several groups of investigators have found that both live weight and good egg production can be maintained on diets with 15 per cent of protein, but Titus concludes that it is safer to rely on diets with 16 to 17 per cent. Likewise for a good hatch of chicken eggs, Titus and also Heiman, Carver, and St. John (Washington Agric. Exp. Sta. Bul., 331, 1936) maintain that not less than 16 per cent of good quality protein should be incorporated in the laying diet.

Procedure

Starting in 1939, four experiments were conducted to ascertain the optimum protein level for breeding bobwhite quail (*Colinus virginianus*). During four successive years, two experiments were made with 48 pairs each and two with 96 pairs each. The birds used in 1939 were of the Schwenk strain and donated by the Virginia Game Commission to the U. S. Fish and Wildlife Service for nutritional studies. Those used in 1940 were the offspring of Virginia stock that had been selected for breeding on the basis of the record of performance by the females, and of high weights. Many of the matings were brother-sister. In 1941 half the F_2 females were mated with F_2 male cousins and the others crossed with pen-reared stock from Pennsylvania. For the final experiment in 1942, the offspring of the above-mentioned crossbred quail and some of the parent stock were used without regard to previous performance.

During the first two years, all breeders were kept in the Patuxent single compartment breeding pens, 30×84×18 inches (Nestler and Bailey, U. S. Fish and Wildlife Serv., Cons. Bull. 10, 1941) except 12 pairs in double compartment pens (single pen divided lengthwise by movable partition). During the third and fourth years, 48 pairs were still held in the Patuxent pens and 48 more were housed in 4-compartment laying pens designed by the Pennsylvania Game Commission. Each compartment was furnished with a waterer, feeder, dust box, grit container, and nest box.

During the last two weeks of March the birds were paired off and started on the breeding diets. Six diets were used in each experiment and conditions for all six were made comparable by using the same number of pairs of breeders of each type of mating, comprising birds of about the same average weight, and housed in the same number of pens

of any one type. The following levels of protein were compared: Experiments I and II—13, 15, 17, 19, 21, and 23 per cent; Experiments III and IV—19, 21, 23, 25, 27, and 29 per cent. In each of the four experiments, all six diets were compounded of two basal feed mixtures together with cod liver oil or fortified vitamin A and D feeding oil (Tables 1 and 2). The diets were used *ad libitum* by the quail. Grit and water were furnished in separate containers.

TABLE 1.—FORMULAS FOR EXPERIMENTAL FEED MIXTURES.
(All figures are percentages)

Experiment	I		II		III		IV	
Protein	Low	High	Low	High	Low	High	Low	High
Ground yellow corn	47.0	28.7	13.3	10.6	52.3	13.6	56.4	17.9
Ground white corn	—	—	25.5	—	—	—	—	—
Ground whole wheat	15.0	15.0	—	—	—	—	—	—
Standard wheat middlings	—	—	15.0	15.0	10.0	10.0	10.0	10.0
Fine-ground heavy whole oats	15.0	15.0	15.0	15.0	—	—	—	—
Dehydrated alfalfa leaf meal	6.0	6.0	7.0	7.0	10.0	10.0	10.0	10.0
Dried skim milk	—	8.0	—	—	—	—	—	—
Dried buttermilk	—	—	—	16.8	12.0	12.0	5.0	5.0
Dried whey	10.0	—	16.0	—	—	—	—	—
N. A. vacuum-dried fish meal	—	12.0	—	—	—	—	—	—
Sardine fish meal	—	—	—	—	—	—	5.0	5.0
Soybean oil meal	—	12.0	—	16.8	4.8	47.0	3.0	45.0
Peanut oil meal	—	—	—	11.3	—	—	—	—
Dried brewers yeast	—	—	—	—	3.0	—	3.0	—
Ground limestone	1.8	2.2	2.3	2.7	2.6	3.1	2.4	3.0
Special steamed bonemeal	4.5	0.4	3.9	2.8	3.8	2.8	3.7	2.6
Salt mixture No. 1[a]	0.7	0.7	—	—	—	—	—	—
Salt mixture No. 2[b]	—	—	2.0[d]	2.0[d]	1.0	1.0	—	—
Salt mixture No. 3[c]	—	—	—	—	—	—	1.0	1.0

[a] Sodium chloride, 5,000 parts; manganous sulfate, tetrahydrate, 406.15.
[b] Sodium chloride, 5,000; manganous sulfate, anhydrous, 42.5; ferrous sulfate, 27.5; copper sulfate, anhydrous, 0.5; potassium iodide, 0.5.
[c] Sodium chloride, 5,000; manganous sulfate, anhydrous, 85; ferrous sulfate, anhydrous, 55; copper sulfate, anhydrous, 2.0; potassium iodide, 3.5; sodium thiosulfate, anhydrous, 3.2; calcium carbonate, 3.5.
[d] For half of the birds on each protein level in Experiment II, the 2.0 per cent of salt mixture No. 2 was replaced with 0.5 per cent of that mixture, adding 1.5 per cent of ground white corn and enough more anhydrous manganous sulfate to raise the manganese level to that obtained with use of the 2.0 per cent of salt mixture.

Eggs were removed from the nest boxes once a week in Experiments I and II and daily in Experiments III and IV except during the height of the breeding season, when they were gathered 3 times a week because of pressure of other work.

The eggs generally were racked within an hour after collection on incubator trays in a water-cooled storage shed, where the summer daytime temperature was 15° to 20°F. below that outdoors in the shade. All experimental eggs were marked with the date of collection and the pen number. Eggs usually were placed in the incubator every two weeks, although occasionally at the peak of egg production, eggs were set every week or ten days so that the resulting hatch would not be too large for accommodation in the brooders.

Once every four weeks the birds and

the unconsumed feed were weighed. The data (Table 3) on live weights, and on production, fertility and hatch of the eggs, were studied statistically by either variance or covariance analysis.

RESULTS

SURVIVAL

Of the 576 breeding quail started on the four experiments, 512 (88.9%) survived the breeding season (females, 90%; males, 88%). Chronic coccidiosis was the main known cause of mortality, and mechanical injury, by accident or fighting, was second. None of the differences as to survival of the breeders according to the level of protein fed was statistically significant.

TABLE 2.—APPROXIMATE CONTENT OF PROTEIN, CALCIUM, PHOSPHORUS, AND VITAMIN IN BASAL FEED MIXTURES.

Experiment	I		II		III		IV	
Protein	Low	High	Low	High	Low	High	Low	High
Nutrient:								
Crude protein (per cent)	*10.1*	*23.4*	*11.9*	*25.0*	*17.0*	*31.0*	*17.3*	*31.4*
Calcium (per cent)	*2.4*	*2.4*	*2.4*	*2.4*	*2.4*	*2.4*	*2.4*	*2.4*
Phosphorus (per cent)	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*
Vitamin A or precursors (I.U.)	6,810[a] 4,240	3,670	6,810[a] 5,140	5,140	6,810[a] 11,190	9,990	6,810[a] 11,320	10,170
Thiamin (I.U.)	240	330	320	570	500	650	480	620
Riboflavin (micrograms)	2,050	2,020	2,850	2,790	2,700	2,600	2,270	2,210
Pantothenic acid (Jukes-Lepkowsky units)	1.1	0.9	1.3	1.6	1.6	1.3	1.4	1.1
Vitamin D (I.U.)[a]	900		900		900		900	

[a] Furnished by fortified cod liver oil or vitamin A and D feeding oil when diets were compounded.

LIVE WEIGHTS

The live weights are averages of all obtained on each sex throughout each of the four experiments. Weight fluctuations for each experiment during the breeding season followed closely a general pattern. The males averaged 171 grams about the first week in April, declined to 165 grams during late June, increased to 169 grams during the next four weeks, and dropped to 165 grams during the second week of September. Females averaged 171 grams at the start of the breeding season, gained rapidly to 191 grams during the last week of May, and then gradually declined to average 163 grams at the close of the season.

In Experiments I and II the differences between the weights of the males on 19 per cent of protein and those on any of other level (except 21%) are highly significant statistically. In Experiments III and IV, males on 25 per cent of protein weighed more than males on the other five levels and all differences are highly significant.

The weights of females were markedly greater on the 23 per cent level in

TABLE 3.—RESULTS IN EXPERIMENTS I–IV AT DIFFERENT PROTEIN LEVELS FOR BREEDING BOBWHITE QUAIL.

Percentage of protein	Exp. No.	13	15	17	19	21	23	25	27	29
Percentage of survival	I, II	97	94	94	97	94	88	—	—	—
	III, IV	—	—	—	86	88	84	86	88	88
Average weight, grams										
Males	I, II	165	162	165	167	166	165	—	—	—
	III, IV	—	—	—	169	169	167	171	167	168
Females	I, II	172	171	170	173	172	176	—	—	—
	III, IV	—	—	—	186	180	184	183	180	184
Feed consumed per bird per day, grams	I, II	15.3	15.6	16.6	16.3	16.5	16.8	—	—	—
	III, IV	—	—	—	17.5	17.9	18.3	18.4	18.3	18.8
Dates of laying										
First egg	I, II	May 13	May 11	May 26	May 13	May 3	May 5	—	—	—
	III, IV	—	—	—	Apr. 22	Apr. 21	Apr. 20	Apr. 24	Apr. 22	Apr. 21
Last egg	I, II	Sept. 2	Sept. 11	Sept. 3	Sept. 12	Sept. 19	Sept. 19	—	—	—
	III, IV	—	—	—	Aug. 30	Sept. 10	Sept. 14	Aug. 31	Sept. 10	Sept. 4
Percentage of females laying during										
Last week in April	I, II	0	0	0	0	0	0	—	—	—
	III, IV	—	—	—	25	22	38	16	31	16
First week in May	I, II	0	0	0	0	13	13	—	—	—
	III, IV	—	—	—	66	53	69	44	63	41
Last week in August	I, II	6	19	20	13	20	36	—	—	—
	III, IV	—	—	—	33	19	52	31	25	27
First week in September	I, II	6	19	7	13	20	29	—	—	—
	III, IV	—	—	—	0	6	13	0	3	7
Eggs produced per female	I, II	36	43	44	47	48	58	—	—	—
	III, IV	—	—	—	61	59	69	57	57	61
Percentage of fertile eggs	I, II	88	91	86	91	90	88	—	—	—
	III, IV	—	—	—	93	93	94	93	94	94
Percentage of fertile eggs hatched										
Outbred birds	I	74	84	78	88	83	82	—	—	—
Inbred birds (siblings and cousins)	II	48	52	55	55	59	45	—	—	—
½ outbred, ½ crossbred birds	III	—	—	—	69	61	70	72	70	70
Outbred birds	IV	—	—	—	82	78	82	75	76	78

Experiment II than those of hens on the other levels, but when the data from the first two experiments were combined, no differences were statistically significant. In the last two experiments, however, the differences in weight of females on 19, 23, 25, and 29 per cent of protein and those on 21 and 27 per cent showed significance.

FEED CONSUMPTION

The quantity of feed consumed per bird tended to increase proportionately with the increase in the level of protein intake in all four experiments.

PRECOCITY AND PERSISTENCE

The birds of Experiments III and IV came into production two to three weeks sooner than those of Experiments I and II. This advance in laying undoubtedly resulted largely from the selective breeding carried on with the experimental stock since nutritional research began at the Patuxent Refuge in 1939. The irregularity of the data obscures any correlation that may exist between precocity and persistence of the females in laying and the level of protein intake of the breeding diet; yet on all four experiments, egg production started earlier and continued longer with the greatest percentage of birds on the 23 per cent level than on any other.

PRODUCTION

The best egg production on Experiments I and II combined was obtained on 23 per cent of protein with an average of 58 eggs per hen for the season. The difference between this and any of the other five levels is highly significant; likewise differences in production on the 21, 19, and 17 per cent levels, and that on 13 per cent are very significant.

On Experiments III and IV, combined, the highest average, of 69 eggs per hen, was also on 23 per cent of protein. In this case, however, the differences are not quite statistically significant. One hen on this level produced 122 eggs, averaging an egg every 33 hours for the breeding season of 168 days.

EGG WEIGHTS

The weights of eggs from Experiments I and II, based on 3,949 weighings, increased in direct proportion with the level of dietary protein from 9.2 grams on 13 per cent to 9.7 grams on 23 per cent. In Experiment III, 4,854 eggs were weighed, but none from Experiment IV. No significant differences were found to exist between the egg weights with various protein levels in the diet. The maximum difference between the average weights of eggs from birds on any two of the six diets throughout the breeding season was only 0.3 gram. There was a range of only 0.6 gram between the average weight of all eggs laid at the beginning of the breeding season (9.3 grams) and that of eggs at the peak of the season (about July 16, 9.9 grams).

EGG FERTILITY

The greatest differences in fertility occurred in the first two experiments. When the data from Experiments III and IV were combined, there was a maximum difference of only 1 per cent-unit between the results from any two diets. The differences were not statistically significant for any of the experiments.

HATCH OF FERTILE EGGS

When the hatching data were subjected to covariance analysis, none of the differences that might be attributed to diet in any of the four experiments proved to be significant. Those in the first two experiments between linebreeding and inbreeding, however, were very significant. The poor hatch manifested on Experiment II undoubtedly resulted from close inbreeding, many of the matings being brother-sister. Despite precautions, more of the closely related pairs were inadvertently placed on the diet with 23 per cent of protein than on any of the other five which may account for the comparatively low hatch on that diet. As soon as a new blood line was introduced into Experiment III, the hatch generally improved.

SUMMARY

From 1939–42 four experiments were conducted at the Patuxent Research Refuge, Bowie, Maryland with breeding bobwhite quail to determine the optimum level of crude protein intake for maintenance and reproduction. In the first two experiments, each with 48 pairs of quail, protein levels of 13, 15, 17, 19, 21, and 23 per cent, respectively, were compared. In the last two, with 96 pairs of quail each, protein levels of 19, 21, 23, 25, 27, and 29 per cent were compared.

The differences in survival of breeders at various protein levels, and the fertility and hatchability of their eggs, were not statistically significant. There were indications, however, that for optimum hatch, the protein should not be lower than 15 per cent.

Maximum egg production was obtained with 23 per cent of crude protein. Production began earlier and continued longer with more birds on this level of protein than on any of the other eight levels.

There was a tendency for the weight of the eggs to increase as the level of dietary protein was raised from 13 to 23 per cent.

The consumption of feed increased in direct proportion of increase in the crude protein content of the diet.

For both males and females, protein levels of 19 to 25 per cent were satisfactory for maintenance of body weight.

WINTER HABITS OF CROWS IN OKLAHOMA

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The crow is one of nature's most adaptable animals, else it would never have survived the persecution of the past 30 years. Instead of being reduced by diverse control activities, it has steadily increased. This has resulted from the extension of suitable wintering and summering grounds through agricultural development. Since the beginning of the present century, much of the nesting territory in Canada has been changed from bush into wheat farms, thus increasing and improving the summer range for the bird. Kalmbach (1937) and Kalmbach and Aldous (1940) showed that the northern limits of the crow's nesting territory closely approximate those of agriculture.

In its winter range, the extension of farming in western Oklahoma, Texas, and Kansas has provided an abundant winter food supply interspersed with ideal roosting sites. Kalmbach (1918) listed only a few large crow roosts in northeastern Oklahoma. Today, roosts are distributed over much of the state; there are eight large ones within a 25-mile radius in the central section. Because of this increase, depredations by crows on agricultural crops have increased in parts of the Southern Plains Area and farmers are forced to combat the birds and to alter certain old farming practices to save their crops. From October 1935 through March 1936, the author studied the situation and investigated the possibilities of control. The subject matter of this paper, however, deals with matters incidental to the main purpose of that project.

The crows wintering in central Oklahoma are referable to two forms. The weights and measurements of 301 taken February 11, 1936, near Verden, Oklahoma, and examined by Dr. Harry C. Oberholser and the author indicated that 72 per cent were *Corvus b. brachyrhynchos* and the others were *C. b. hesperus*. The average weights in grams were: *brachyrhynchos*, females, 446.4; males, 502.2; *hesperus*, females, 426.9; males, 472.9.

Movements

Migrations into central Oklahoma start in September, but the incoming flocks are not of any great size until October with the first cold days of autumn. The maximum population usually is reached about mid-November, and from then until late January remains quite constant. The birds begin to drift out during early February toward spring roosts to the north, often at places where heavy concentrations do not occur during the autumn. The decrease is particularly noticeable during late February and early March. By March 21, when my studies terminated, only a few were left in the area. The seasonal migrations, as determined by banding returns, have been discussed elsewhere (Kalmbach and Aldous, 1940).

Factors Conducive to Local Abundance

The winter concentrations in Okla-

homa result from a combination of favorable factors: (1) large acreages of thick brush as attractive roosting sites; (2) abundance of grain sorghums, Indian corn, spring oats, and wild fruits as a bounteous food supply; and (3) the relatively mild winters and many watering places. Crop reports from each county and an appraisal of the environment for winter abundance of crows provided material for the accompanying map (Fig. 1), which shows the location of known occupied roosts in 1935–36 and the effects of grain crops, roosting sites, and suitable terrain on the distribution of crows.

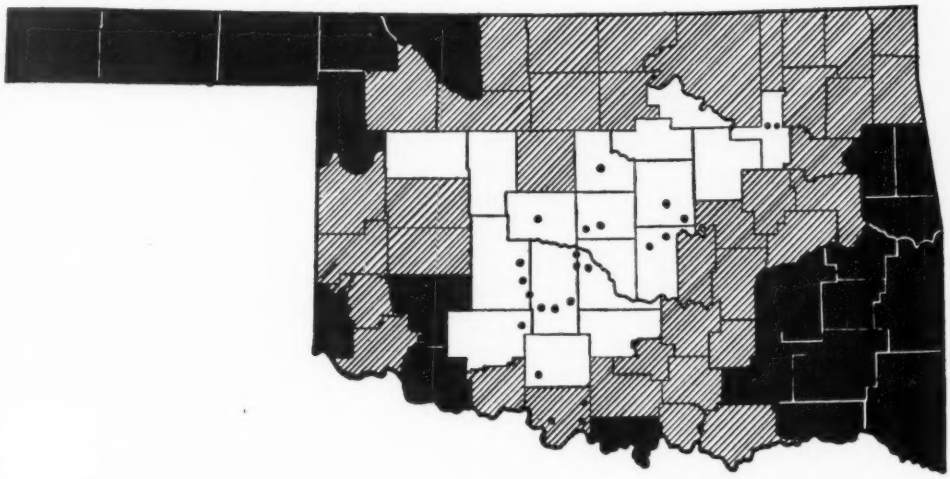

Fig. 1. Distribution of crops and of suitable roosting cover in Oklahoma in relation to winter abundance of crows. The black areas lack a proper balance between food and roosting cover. The shaded areas have acceptable crops in greater abundance and some suitable roosting cover. The unshaded areas have both abundant food and adequate terrain requirements for many crows. The dots indicate approximate location of crow roosts known to the author in the winter of 1935–36.

The western and northwestern counties have agricultural crops quite attractive to crows, but lack suitable sites for roosts. This area is colder and more windy than the central part of the state, and has fewer watering places. The eastern counties, on the other hand, abound in suitable roosting sites but the land is devoted largely to grazing and oil production and has no large acreages of sorghums or corn for food. The central part of the state possesses all necessary requirements and the birds are most numerous there.

Roosts

In central Oklahoma crow roosts are most common in scrub oak thickets although trees of other species sometimes are used. Hillsides protected from the wind are usually chosen. The area of a roost varies with the number of birds occupying it, and may be from a few to 20 or 30 acres. Often the birds roost very compactly so that even small acreages of brush harbor unbelievably large numbers. Imler and Kalmbach (1939),

estimated that one bird per two square feet of ground surface covered by the trees was not uncommon in the roosts they studied. Applying this ratio to some roosts in thick brush would account for up to 20,000 birds per acre in the center of a roost.

A roost can be found by observing evening or morning flight lanes. At times this may be difficult by reason of rough country and impassable roads, but patience and effort usually are rewarded. The habit of crows to shift from a main roost to temporary locations during periods of disturbance, complicates matters and also gives the casual observer the impression that permanent roosts are more numerous than actually is the case; intensive campaigns of shooting and bombing tend to increase such changes. Such shifting is well illustrated by the history of one flock. In October the birds occupied a roost three miles west and one mile south of Norge, Oklahoma. Early in November they moved two and one-half miles to a roost one-half mile west of Laverty and remained until about January 20, then deserted the roost to move three miles and join an enormous roost five miles south and one mile west of Verden.

The exact location of 17 roosts was determined and the general position of seven others was reported by local residents. In each case, however, the number of crows in the vicinity was evidence of a nearby roost. The largest was five miles south and one mile west of Verden, Oklahoma; on November 19 it was conservatively estimated to harbor 200,000 crows. Quite accurate counts were made of the arriving birds until about 40,000 had entered, after which they came so fast that counting was impossible. They approached in a solid bank from three-fourths of the horizon and from as far as field glasses could reach; a rough estimate was of 25,000 in view at one time, and they continued to arrive at that rate for 45 minutes. The noise was almost deafening as each attempted to find its spot to roost. After the last had arrived, there was quiet, except for an occasional quarrel, and the roost location could not be detected by sound.

DAILY MOVEMENTS

The birds started to leave the roosts shortly before daybreak and by the time it was light most of them had gone. By sunrise they usually were feeding in the fields. During the day they cruised as much as 8 to 12 miles from certain roosts, sometimes in all directions, but from other roosts in only one or two directions. Daily movements were governed by the direction of the feeding grounds. In the evening the crows started toward the roosts one or two hours before sunset. The first entered about sundown and shortly thereafter the main influx occurred. At some large roosts the return was not complete until an hour or more after dark.

The individual flight lanes radiating from the roosts are travelled largely by the same groups of birds from day to day. Proof of this was obtained by trapping and banding and by experiments directed towards reducing the numbers of crows. At one group of traps, where 476 were banded and released, a total of 188 re-entries into the traps were recorded. This indicated that many of the same individuals were returning to this area and also that crows are not unduly frightened by being caught and handled.

If the birds were in the habit of shifting to different flight lanes, such handling certainly should have been a sufficient cause for them to do so.

Along another flight lane, used by a large group when the study started, intensive control so reduced the number that few could be found there after the control was finished. Adjacent flight lanes were not altered so it was felt that again a particular group was using a given lane. This lane was practically unused for about 4 weeks after the control ceased, then a few birds started shifting to it from other lanes.

UTILIZATION OF CROWS

The killing of thousands of crows by bombing directed attention to the possibility of utilizing the dead birds to offset the cost of control, aimed at curtailing their depredations.

A physician in Tulsa encouraged the eating of crows by serving them to friends at a banquet. His guests pronounced them delicious, and since then crows have been served at clubs, banquets, auctions, churches, and homes—*with the general conclusion that they are good meat.* My opinion, after eating them, is that they are as good as doves or ducks. In the spring of 1936 produce men in Oklahoma City collected bomb-killed crows by the thousands, and dressed birds were on sale in numerous meat markets at 19 cents each.

A few were dressed out, and the feathers, head, feet, and entrails proved to form about 42 per cent of the gross weight. Since the average crow weighs about 460 grams (16.2 ounces), the dressed weight would be 266.8 grams (9.4 ounces). If the eating of crows could be encouraged long enough to remove the current prejudice against this bird and its game qualities, this would go far toward solving the crow problem in areas of overabundance.

Several farmers said that crows make excellent hog feed and one near Agawam, where a crow roost was bombed, fed the birds to his hogs and reported them a good food. They would appear to be as good as the carcasses of horses and cows commonly fed to hogs.

An effort was made to induce farmers near bombings to use the dead birds as fertilizer and a few plowed them under. This practice would provide sanitary disposal of the carcasses and also help to build up the soil.

Feathers from the back and breast of the crow are excellent for pillows and feather beds. They are superior to chicken feathers because the tips of the quills are blunter, lessening the chance of passage through the ticking. One farmer's wife near Agawam, retrieved crows from a bombing and plucked the feathers; about 21 birds yielded a pound of feathers and between 700 and 800 were needed for one feather bed.

FOOD HABITS

During most of October and until the first really cold weather, the crows fed largely in alfalfa fields and along creek bottoms, where their main diet was of insects and wild fruits. The cold weather killed most of the insects and started the grain sorghums to mature; as soon as these late maturing grains are in the dough stage they are subject to frequent visitations by crows. During years of drought or of poor crop production from other causes, the losses from crows are always greater than

when food is abundant. On November 11 the writer estimated 10,000 crows to be feeding in sorghum fields along a two-mile stretch of road. When the birds become too troublesome it has been necessary for the farmers to cut their grain and shock it around the farmyards to minimize losses by crows. The patrolling of fields is effective but must be done from daybreak until dark. The old practice of leaving shocked grain in the field until needed will have to be abandoned if a minimum of crow damage is desired. Planting earlier varieties will aid materially in reducing such losses, where soil and moisture conditions permit.

Indian corn, peanuts, watermelons, pecans, and small grains also are preyed upon by crows but in the aggregate the acreages are so small that they represent only very local problems. To individual farmers, however, losses inflicted on these crops may be serious, and must be dealt with if their livelihood is to be maintained.

During most of December and January the crows forage widely, eating almost anything available. Shocked grain left in the fields over winter is a marked attraction to them and unless efforts are made to remove the grain from the field or to fight the birds, there is little left by spring. Soft kerneled grains, such as milo maize, Hegari, and kafir corn, are much more subject to depredations than harder varieties, such as red-topped cane. Stock feeding lots and corrals usually harbor flocks of crows all winter as do slaughter houses and garbage dumps.

During the colder months much can be learned of the food of crows by studying their pellets which abound at long-established roosts. These pellets are regurgitated soon after the birds arrive at their nightly abodes, as was learned at a bombed roost. The stomachs of 295 crows killed two hours after entering the roost were opened for study and only 23 (7.8%) contained food: the remainder of the birds had already disgorged all indigestible matter in pellets.

Early in February spring plowing commences and is always attended by crows that make short work of grubs and other invertebrates so exposed. Plowing is soon followed by the planting of spring oats, which again attracts large flocks. Farmers usually accuse the birds of going down the drill marks and pecking out every kernel, but observations have shown that despite heavy crow visitations during planting, sufficient grain remains to produce a crop. A few kernels may be taken from covered drill marks but it is mainly the uncovered grain that attracts the birds. Proper preparation of the soil to avoid large clods and good drills with drag chains functioning properly will usually reduce such loss to a minimum. The greatest waste is at the turns where the drag chains do not cover the drilled grain; but cross drilling over these areas usually ensures a good stand. The interim, before these turn areas are redrilled, provides the birds with most of the grain they consume. All crow visitations cease in one to two days after the oats are planted, indicating that all the grain is not removed by the birds. It is quite certain that crow visitations to newly planted oat fields rarely make replanting necessary.

Shortly after the spring oats are sown,

the crows begin to leave these areas and to drift north and west into the wheat growing sections. No studies were made in the latter, but it is believed that the activities of the crows there are similar to those in the spring-oats area.

SUMMARY

1. During the past 30 years, crow populations have increased in the wintering areas of Oklahoma because of more extensive agriculture both in Oklahoma and in the nesting areas in Canada. The favorable response of crows to the improved winter environment has more than offset the effect of control measures against them.

2. The birds start to migrate into central Oklahoma in September, reach their maximum winter population about mid-November, and begin to leave during early February.

3. Local factors conducive to large winter concentrations are the combination of an abundant food supply, favorable roosting sites, and mild winter climate.

4. Roost populations vary from small groups up to 200,000 or more. Roosts can be found by following evening flight lanes or by inquiry among local residents. Individual birds use the same flight lane and same general feeding area each day.

5. Crows can be utilized for human food, hog food, fertilizers, and feather products.

6. The food of crows in central Oklahoma in the early autumn is largely of insects, wild fruits, early-maturing grain sorghums, and Indian corn. During late autumn and winter they consume late-maturing grain, or that left in the field, and any that can be pilfered from corrals, hog lots, and feed stacks. In the spring the food changes largely to insects exposed by spring preparation of the soil and to spring oats.

7. Pellets are regurgitated within two hours after crows enter a roost.

8. Approximately 72 per cent of the birds taken from a roost near Verden, Oklahoma were *Corvus brachyrynchos brachyrynchos* and the others *C. b. hesperus*.

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EXPERIMENTAL FEEDING OF CAPTIVE FOX SQUIRRELS

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Studies with captive fox squirrels (*Sciurus niger*) to determine the nutritive value of certain foods were made from January 18 to April 15, 1943, at the Swan Creek Wildlife Experiment Station, Allegan County, Michigan. Preliminary trials in 1942 serve to test methods of handling the squirrels, and to obtain some idea of their food preferences and reactions to confinement. The limited nature of these experiments and the lack of previous work warrant no definite conclusions, but the general results may help wildlife managers working with these squirrels.

Six individuals, 2 adult females, 2 adult males, and 2 immatures, were used. They were relatively tame, having been captives for some time in outdoor exhibition pens, where the two immature animals had been born and reared. During the experiments, the squirrels were confined in individual cages in an animal room. Each cage was of steel wire, about 38×30×16 inches in size and had a removable collecting tray beneath the wire floor.

Acorns of the white oak (*Quercus alba*), black oak (*Q. velutina*), and red oak (*Q. borealis maxima*), together with walnuts (of *Juglans nigra*) and yellow dent field corn were the foods tested; acorns are the principal squirrel foods in this locality. All items, except the red oak acorns, were gathered locally and stored in a cool, dry place until used.

At the outset of the study, the squirrels were conditioned to their new surroundings for 10 days and offered each of the various foods to determine preferences. Then they were divided into two groups, test and control, of an adult female, adult male, and juvenile in each. The former were placed on a single-item diet for 15 days and the control group had access to all foods. Test and control groups were alternated so that 15 days intervened between trials with each. All of the squirrels were fed and weighed on alternate days. Weight records were kept of each kind of food given, of the water consumed, the feces, and of any unused food. The squirrels were weighed to the nearest gram and the materials to 0.01 gram.

For each test, representative samples of the food and of the feces were analyzed at the Chemistry Laboratory of the Michigan Agriculture Experiment Station, though the cooperation of Drs. E. J. Miller and E. J. Benne and members of the analytical staff. Determinations were made for water, ash, crude fiber, ether extract, protein, and nitrogen-free extract; results were computed on both moist and water-free bases, but the former is used in the discussion and tables. Morrison's "Feeds and Feeding" (1941) served as a guide in calculating digestibility and nutritive values.

The percentage of each nutrient digested was found by subtracting the amount in the feces (not digested) from that in the food consumed, and then dividing by the amount consumed. The

percentage of each digestible nutrient was obtained by multiplying the percentage in the food by that digested. Thus, white oak acorns contained 5.9 per cent protein of which 38.4 per cent was digested: $5.9 \times 38.4 = 2.27$, the percentage of digestible protein in these acorns.

The total digestible nutrients in each kind of food was found by adding the actual amounts of digestible crude fiber protein, nitrogen-free extract, to that in the ether extract ($\times 2.25$); the energy value of the ether extract (fat) for animals is about 2.25 times that of other nutrients.

The nutritive ratio was determined for each food by dividing the total nonnitrogenous nutrients (including fat $\times 2.25$) by the digestible protein.

TABLE 1.—EXPERIMENTS ON FOOD PREFERENCE WITH FOX SQUIRRELS, 1943.
(All weights in grams)

Squirrel	Food consumed							Change in body weight[a]
	Acorns			Walnuts	Corn	Total	Daily average	
	White oak	Black oak	Red oak					
Juv. female, 16,323	190	104	104	54	47	499	49.9	+ 96
Juv. male, 16,324	250	93	40	5	47	435	43.5	−112
Ad. female, 15,879	73	92	45	80	14	304	30.4	+ 1
Ad. female, 7,024	181	45	68	13	12	319	31.9	− 57
Ad. male, 7,025	94	136	55	42	6	333	33.3	− 18
Ad. male, 15,878	185	104	48	0	26	363	36.3	− 86
Totals	973	574	360	194	152	2,253	225.3	−176
Averages per day per squirrel	16.2	9.6	6.0	3.2	2.5	37.55		−2.9

[a] Much of the loss probably resulted from squirrels not being accustomed to new and smaller quarters and to being handled.

FOOD PREFERENCES

As determined by the amounts eaten, the food preferences were in the following order: white oak acorns, black oak acorns, red oak acorns, walnuts, and corn (Table 1). Tests in 1942 on amounts eaten showed that squirrels preferred all of the other foods to red oak acorns. Nicholson (1937) found that fox squirrels preferred walnuts, hickory nuts, and various acorns to red oak acorns; he attributed the low appeal of the last to their bitter taste. Tannin, probably the cause of the bitter taste, was found by Wanio and Forbes (1941) to amount to 6.04 per cent in red oak acorns, 2.94 per cent in white oak acorns, and only 0.24 per cent in walnuts.

WHITE OAK ACORNS

The test squirrels ate an average of 50.7 grams per animal per day and gained 1.3 grams in weight. The control group averaged 35.5 grams of food per squirrel per day and gained only 0.8 grams (Table 2). Test squirrels used

TABLE 2.—AVERAGE AMOUNTS OF FOOD AND WATER CONSUMED, FECES EXPELLED, AND CHANGE IN WEIGHT OF FOX SQUIRRELS, 1943.
(Grams per squirrel per day)

TEST SQUIRRELS	*Food*	*Water*	*Feces*	*Change in weight*
White oak acorns	50.7	15.7	10.5	+1.3
Black oak acorns	29.4	23.5	9.7	−0.4
Black walnuts	23.8	34.2	5.6	+1.4
Corn	20.1	23.9	7.5	−3.2
Red oak acorns	30.7	25.5	7.0	−2.6
CONTROL SQUIRRELS				
White oak acorn test	35.5	22.6	9.1	+0.8
Black oak acorn test	38.8	23.4	10.2	+0.7
Black walnut test	33.5	20.2	7.4	+1.0
Corn test	28.8	25.3	8.6	+0.6
Red oak acorn test	32.2	30.6	7.4	+1.2

15.7 grams of water per day per individual, less than taken by squirrels on any other diet.

Acorns of the white oak are higher in water and crude fiber, and lower in ash, ether extract, and total digestible nutrients (71.22%) than any of the other foods (Table 3); they also are low in protein, the ratio of protein to non-protein nutrients being 1:30.4. The low total of digestible nutrients, and the fact that test squirrels consumed more of white oak acorns, possibly indicates that they had to eat more of them to satisfy their nutritive requirements.

BLACK OAK ACORNS

On this diet the test squirrels lost an

TABLE 3.—TEST FOODS USED WITH FOX SQUIRRELS.
(All figures are percentages except nutritive ratio)

	Water	*Ash*	*Crude fiber*	*Ether extract*	*Protein*	*Nitrogen-free extract*
ANALYSES[a]						
White oak acorns	24.29	0.82	3.05	4.41	5.92	61.51
Black oak acorns	9.04	1.85	2.69	20.90	6.29	59.23
Black walnuts	10.95	2.99	1.91	32.87	29.04	22.24
Corn	14.12	1.63	2.02	5.60	10.02	66.62
Red oak acorns	14.88	2.67	2.40	16.06	5.92	58.07
DIGESTIBILITY[b]						
White oak acorns		62.4	86.3	88.3	38.4	93.6
Black oak acorns		52.1	75.8	93.4	21.3	91.0
Black walnuts		39.2	9.2	97.7	88.9	90.0
Corn		*	45.1	63.6	59.1	92.5
Red oak acorns		79.0	88.5	94.6	39.3	95.1
	Nutritive ratio	*Totals*				
DIGESTIBLE NUTRIENTS						
White oak acorns	1:30.4	71.22	2.63	3.89	2.27	57.57
Black oak acorns	1:74.5	101.20	2.04	19.52	1.34	53.90
Black walnuts	1:3.6	118.24	0.18	32.11	25.82	19.99
Corn	1:11.9	76.46	0.91	3.56	5.92	61.62
Red oak acorns	1:39.3	93.85	2.12	15.19	2.33	55.22

[a] Excluding shells of acorns and walnuts and corn cobs.
[b] Also called coefficient of digestibility.
* Analysis showed more ash in the feces of all 3 squirrels than contained in the corn consumed.

average of 0.4 grams per day, while the control animals gained 0.7 grams. These acorns were lower in water content than any of the other foods. They also were low in protein and, more importantly, the squirrels were able to digest only 21.3 per cent of it, much less than in any other food. The digestible nutrients totalled 101.20, and the nutritive ratio was 1:74.5.

WALNUTS

On the basis of quantity eaten, walnuts were next to last as a preferred food, but they produced the greatest gain in the test animals and contained the largest percentage of digestible nutrients. The test animals gained 1.4 grams per day for every 23.8 grams of walnut meats eaten. The walnuts fed during this test were pre-cracked, while those fed during the preference test were entire. Pre-cracked walnuts were eaten readily but those with intact shells were not.

Walnut meats contain higher percentages of ash, ether extract, and protein, and less crude fiber than the other foods. Squirrels were able to digest a much greater percentage of the protein in the walnuts than in the other items; the nutritive ratio being 1:3.6.

YELLOW DENT CORN

Corn was least preferred of all foods tested (Table 1). The test animals ate less per day (20.1 grams) and lost more weight (3.2 grams) than on any other diet. The corn was low in ether extract and a smaller part of it was digestible than with any of the other foods. Corn contained 76.46 per cent digestible nutrients, and had a nutritive ratio of 1:11.9. Morrison (1941) gives the per cent of digestible nutrients in dent corn as from 74.2 to 83.7 per cent, and the nutritive ratio as 1:10.3. The test squirrels, when confined in the outdoor exhibition pens, were fed the same grade of corn later used in the experiments. They ate it readily and seemed to keep in good condition.

RED OAK ACORNS

Test animals consumed 30.7 grams per day and lost 2.6 grams in weight, whereas the control group on 32.2 grams gained 1.2 grams. Red oak acorns were low in protein but about average in other nutrients; the latter were notably higher than for red oak acorns in Pennsylvania reported by Wainio and Forbes. They are also higher than those recorded by Morrison, who gives the total digestible nutrients as 34.9 and the nutritive ratio as 1:57.2.

In preliminary experiments at Swan Creek during 1942, these acorns were least preferred of all the foods tested and two of the three test animals died within 10 days on them. The red oak acorns then used were gathered near the station, but those tested in 1943 were gathered elsewhere.

DISCUSSION

The poor quality of red oak acorns as squirrel food is shown by loss of weight or death when used as an exclusive diet. This throws some light on the observation that squirrels, during a good acorn year (and also deer and raccoons) feed on white and black oak acorns but almost completely ignore those of the red oak so long as a supply of the former two is available. White and black oaks, therefore, should be given preference over red oak in selective cutting or

planting for improvement of squirrel habitat. At Swan Creek these three are the only species of oaks of practical importance. The value of white oak is further enhanced by high rating as a den tree. Walnuts are important in squirrel management, but secondary to the acorn trees which produce the staple food. The results with field corn were somewhat contradictory and further tests are needed before drawing conclusions as to its nutritional qualities; generally, its use by squirrels is secondary to natural foods.

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ADDITIONAL STUDIES ON TAGGED YOUNG MUSKRATS[1]

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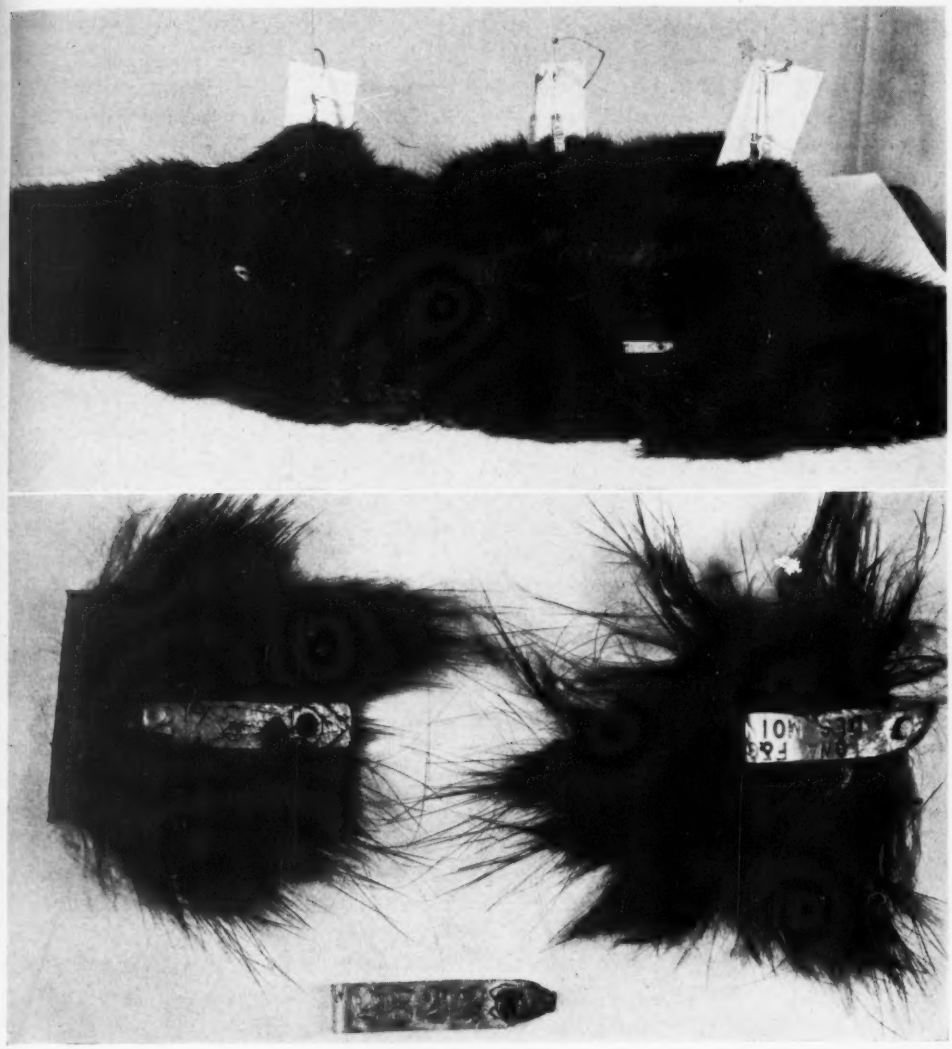
The results of experimentally tagging 463 young muskrats (*Ondatra z. zibethicus*) in northwestern Iowa during the summers of 1935 and 1936 were summarized by Errington and Errington (1937). In 1935 our efforts to fasten serially numbered aluminum tags to the skin of the back out of reach of the teeth were not very productive, chiefly because the skin enclosed by the loops of the sealed tags was killed. By 1936 the tagging procedure had been greatly improved, and there was little evidence of animals losing their tags or suffering detriment because of the tagging. Of 124 muskrats tagged when between 10 to 27 days of age in 1936, 14 were recovered the following winter and spring at ages between 161 and 345 days; 21 others were taken after lesser intervals but long enough to contribute significantly to our knowledge of development and behavior during stages of early independence.

Takos (1943) has reported virtually complete failure of experiments in Maine that involved back-tagging of 37 individuals (68 attempts in all, one muskrat having been tagged six different times). He found the "longest period that any animal banded by the Errington method was known to have retained its tag was 28 days; and it then was apparent that the skin loop soon would have sloughed off. . . . Failure . . . was believed to be related to water pollution and to the further fact that muskrats of all ages were being tagged" (Takos, 1943: 403).

The conclusions of that author as to the ineffectiveness of back-tagging under the circumstances described seem

[1] Journal Paper No. J-1196 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 498. Iowa State College, Iowa State Conservation Commission, American Wildlife Institute, and U. S. Fish and Wildlife Service, cooperating.



A. Five muskrats tagged as suckling young and recovered from private fur trappers as subadults aged 182 to 201 days. All photographed in the flesh to demonstrate the appearance of tags in fur (foreground) and strength of the skin bridges by which tags were held (background). *B*. Tags bitten by muskrats. Those above, with squares of skin attached, were carried nearly a half year; the lower tag was carried for only about two weeks, when the muskrat died in a violent rain storm.

reasonable to me, although I suspect that the possible role of pollution was of less consequence than the age of the animals when tagged. Compared with the established vascular system in the skin of an adult, the circulation in the skin of a rapidly growing young muskrat should be reoriented more easily to nourish a strip cut off on two sides by a metal tag. (Before reading Takos' paper, I had not given much consideration to this rather elementary point and felt that the Iowa method, tried on and recommended for young only, probably would serve for marking adults as well.)

The Iowa studies, insofar as they did not entail back-tagging of any muskrats older than two months and few older than one month, afford no precise information on the ages or developmental stages at which the method becomes unreliable. Experience with animals tagged in the second to fourth week, however, continued to be so satisfactory that publication of the data accumulated since 1936 seems desirable. (For criteria on age and development see Errington, 1939b.)

No tagging was done in 1937, but the winter of 1937–38 brought reports of three animals tagged in May and June, 1936, on Round Lake, near Ruthven, Iowa, and caught by private trappers in November, 1937, at ages of 521 to 560 days, on Mud Lake and Barringer's Slough, at 2¼ to 3¼ miles from the sites where tagged. Other tagged muskrats were said to have been caught but not reported by trappers, who feared that possession would be construed as evidence of poaching on Round Lake, a state wildlife refuge. These also, according to "grapevine," were caught within a four-mile radius of where tagged, near or on the first main bodies of water likely to attract muskrats wandering from Round Lake.

Early in December, 1937, 208 muskrats were trapped on Round Lake for research purposes by State Conservation Officers C. C. Lille and L. D. Wright. This sample represented 30 per cent of a calculated early winter population of 687 on the basis of data including sex and age ratios (for procedures to calculate early winter densities, see Errington, 1943: 805–806). None of 44 adult animals (born in or before 1936, the last season of previous tagging) bore tags. In November and December, 1936, state trappers had taken 181 specimens or 40 per cent of an early winter population calculated at 452; and, of 133 young, 12 had borne the tags of 1936 (Errington and Errington, 1937: 51–52, 58). Of a calculated 1936–37 winter population close to 200 young surviving the state collecting, about 18 should have been bearing tags. In view of the fairly hazardous living conditions at Round Lake during that low-water winter (Errington, 1939a: 179, 182–184), and the number of tagged muskrats known to have been trapped privately on neighboring marshes the next autumn, it seems improbable that more than a few of those marked in 1936 actually remained on Round Lake by the winter of 1937–38.

Tagging studies were resumed on Round Lake in 1938, when 128 tags were placed on members of 26 litters from May 16 to July 7. This was done principally to clarify the identity of "key" litters in studies on the rates of growth and development in the second month after birth; and few individuals seen to be bearing tags were collected

during the summer. In late November and early December, 1938, carefully planned trapping in representative parts of Round Lake by Lille and Wright, aided by Horace L. Poole, yielded samples totalling 206 specimens—39 adults and 167 young; three of the latter bore tags. The 1938 lot of state-trapped specimens represented approximately one-third of the population of 633 calculated to have entered the winter of 1938–39.

No tagging was done the following summer, but, of 201 specimens trapped by Lille and Wright in late December 1939, 33 were adults, of which two had been tagged as young in 1938. The 201 specimens represented 16 per cent of an early winter population calculated at 1,278, but a December 1939 population of 199 adults comprised less than half of the initial population figure of 429 adults arrived at, as of early summer.[2]

Thirty-one young back-tagged at Wall Lake, southeast of Clarion, in north-central Iowa, during the summer of 1940, were exposed by drought and never heard of again (see discussion of toe-clipping below).

No additional tagging was done until late May 1943, when 21 young on Cheever Lake and 34 on Four Mile Lake, neighboring marshes near Estherville, northwest Iowa, were marked by State Conservation Officer E. M. Wogen and the author to test the effectiveness of a system of breeding stock refuges on state-administered public hunting and trapping grounds. The few tags placed (in two half-days) were largely counterbalanced by the thoroughness with which Wogen explained objectives of the study to local trappers and secured their cooperation in watching for and turning in tagged and other specimens, together with information as to time and site of capture. The tag-bearing animals were purchased at premium rates ($3.00 each) in fresh and unskinned condition.

Of the Cheever Lake young, 16 were members of two litters (about 13 and 15 days old when tagged, May 26) kept in lodges on a part of the marsh closed to trapping; none of them was recovered. A third litter of five (about 35 days of age) was tagged the same day on a part of Cheever Lake subject to fur trapping during the 1943–44 legal season; no tagged animals of this litter were reported as taken, but a trapper thought that one of his catch had lost a tag.

On Four Mile Lake, 11 young (two litters, about 15 and 25 days old) tagged on May 27 were occupants of a refuge tract; none was recovered, although their natal lodges were near to the boundary of the area open to trapping. Likewise nine young (about 30 days old) of a litter tagged in the "open" area were not heard of subsequently. One of a litter of five (tagged when about 25 days old) was recovered in autumn trapping in the vicinity where tagged. The fifth and last litter tagged on Four Mile Lake really made a show-

[2] Reason for adult decline: Differential mortality during a fall drought. Offspring of shallow-zone parents tended to migrate centripetally and to establish themselves with some security in deep-water habitats during late summer (characteristically a period of minimal friction), whereas the old ones tenaciously retained their "property rights" along the exposed marsh border until too late in the autumn for them to make adjustments without terrific mortality through intraspecific strife (Errington, 1940: 181–182).

ing—of nine 12-day young tagged, six were taken as subadults living close together in a small area 100 to 150 yards from the site of tagging.

The trapping pressure in 1943–44 on "open" areas of both marshes was intense, and Wogen accounted for 2,352 muskrats legally caught on Cheever Lake and 1,815 on Four Mile Lake, or about 10 per acre. Of 523 carcasses examined from Cheever Lake, 467 were young, and of 308 from Four Mile Lake, 264 were young.

Table 1 presents previously unpublished data on individual muskrats tagged as suckling young and recovered at free-living ages. It is intended, in combination with the earlier report (Errington and Errington, 1937: Tables 1 and 2, pp. 51–52, 54–56), to make conveniently available to anyone interested the gist of the case histories of Iowa-tagged muskrats that yielded important information.

Few data have been obtained from individuals marked other than by tagging. In the summer of 1937, 35 young on Little Wall Lake, a marsh south of Jewell in central Iowa, were toe-clipped according to the code advocated by Ashbrook (1936). The marsh was expected to and did become dry in late summer and early autumn; I had hoped to be able to follow distinctive tracks of the toe-clipped animals in mud or snow, but the losses through drought turned out to be nearly annihilative (Errington, 1939a: 183) and nothing was learned of these individuals after marking.

Another attempt to found a study of distinctive tracks on a drying marsh was made on Wall Lake (not Little Wall Lake) in 1940. Fifty-three young were toe-clipped, and 23 of them, 11 days old or older, also were tagged. Eight others were marked by tagging only, making a total of 61 marked by one or both methods. As on Little Wall Lake in 1937, losses directly or indirectly from drought were extremely heavy (Errington, 1943: 859, 881–882; Errington and Scott, 1944); a single animal with clipped toes (about 180 days of age when taken about November 20) appeared among 105 specimens comprising over half of the 1940–41 catch of private trappers, who took essentially the entire drought-exposed population remnant. Of the marked young, 38 were of litters in parts of the marsh where the loss of young was virtually complete before the trapping season opened; the other 23 marked young were kept in an area where the females successfully raised an average of about four up to the beginning of trapping in the autumn.

Muskrats lose toes naturally in varying degree, even before being subjected to trapping, freezing, and the hazards of active life, as may be seen in handling large numbers of young. On two particular occasions I expectantly consulted the toe-clipping records to learn the identity of the makers of interesting tracks, only to find that none had been so marked. The likelihood of difficulty from this cause may be offset in part by clipping forefeet according to the same code pattern as the hind feet; the chances of an individual accidentally losing corresponding toes on both fore and hind feet would seem remote. Undue mutilation of feet or loss of blood (especially in freely-bleeding, very young animals) must be guarded against.

TABLE 1.—INDIVIDUAL MUSKRATS TAGGED IN IOWA AS SUCKLING YOUNG AND RECOVERED FREE-LIVING AT VARIOUS AGES.

Serial number, Iowa F. and G Comm. tag	Tagged	Recovered		
	Place, date, and known or calculated age	Place, date, and distance from site where tagged	Length, weight, and known or calculated age	Sexual development when recovered
2667	S. central edge, Round Lake; May 26, 1936; 14 days	S. side, Mud Lake; Nov. 15, 1937; about 3¼ mi.	Medium sized (report by trapper), 552 days	Not examined
2671	S. central edge, Round Lake; May 27, 1936; 19 days	NW. corner Barringer's Slough; about Nov. 20, 1937; about 2¼ mi.	No size data (report by trapper), 561 days	Not examined
2744	Center of Round Lake; June 27, 1936; 18 days	Barringer's slough; Nov. 12, 1937; about 3 mi.	No size data (report by trapper), 521 days	Not examined
2766	NW. edge of Round Lake; May 15, 1938; 9 days	NE. center of Round Lake; Dec. 2, 1938; about 900 yds.	476 mm.; 856 g.; 210 days	Subadult female
37	E. central edge, Round Lake; May 20, 1938; 18 days	SE. center of Round Lake; Dec. 30, 1939; about 375 yds.	591 mm.; 1,313 g. (alimentary tract nearly empty); 607 days	Adult female (about 20 placental scars of 3 litters in 1939)
2801	NW. edge, Round Lake; June 11, 1938; 15 days	NW. edge, Round Lake; Dec. 3, 1938; about 200 yds.	517 mm.; 846 g.; 190 days	Male, subadult, testes, 8.5×5.5 ×4.0 mm.
2829	NE. center, Round Lake; June 17. 1938; 11 days	NE. center, Round Lake; July 10, 1938; about 30 yds.	298 mm.; 196 g.; 34 days	Female, weaned less than 2 weeks
2838	NW. center, Round Lake; June 18, 1938; 13 days	N. center, Round Lake; Dec. 28, 1939; about 950 yds.	570 mm.; 1320 g.; 571 days	Adult female; uterus large, thick, like typical adult, but no placental scars
2842	NE. corner, Round Lake; June 19, 1938; 9 days	NE. corner, Round Lake; July 16, 1938; about 45 yds.	305 mm.; 215 g.; 36 days	Female weaned less than 2 weeks
2858	E. central edge, Round Lake; June 23, 1938; 11 days	E. central edge, Round Lake; Nov. 30, 1938; about 130 yds.	510 mm.; 861 g.; 171 days	Subadult male, testes, 8.5×6 ×5 mm.
756	N. central edge, Four Mile Lake; May 27, 1943, 12 days	W. center, Four Mile Lake; Nov. 23, 1943; 100–150 yds.	531 mm.; 755 g.; 192 days	Subadult male, testes, 7×4.5×3 mm.

TABLE 1.—INDIVIDUAL MUSKRATS TAGGED IN IOWA AS SUCKLING YOUNG AND RECOVERED FREE-LIVING AT VARIOUS AGES—(*continued*).

Serial number, Iowa F. and G. Comm. tag	Tagged	Recovered		
	Plate, date, and known or calculated age	Place, date, and distance from site where tagged	Length, weight, and known or calculated age	Sexual development when recovered
760	N. central edge, Four Mile Lake; May 27, 1943; 12 days	W. center, Four Mile Lake; Nov. 21, 1943; 100–150 yds.	561 mm.; 825 g.; 190 days	Subadult male, testes, 7.5×4×3 mm.
765	N. central edge, Four Mile Lake; May 27, 1943; 12 days	W. center, Four Mile Lake; Nov. 13, 1943; 100–150 yds.	550 mm.; 881 g.; 182 days	Subadult male, testes, 9×5×3 mm.
766	N. central edge, Four Mile Lake; May 27, 1943; 12 days	W. center, Four Mile Lake; Nov. 18, 1943; 100–150 yds.	560 mm.; 946 g.; 187 days	Subadult female
1217	N. central edge, Four Mile Lake; May 27, 1943; 12 days	W. center, Four Mile Lake; Nov. 14, 1943; 100–150 yds.	526 mm.; 719 g.; 183 days	Subadult female
1219	N. central edge, Four Mile Lake; May 27, 1943; 12 days	W. center, Four Mile Lake; Dec. 8, 1943; 100–150 yds.	520 mm.; 765 g.; 207 days	Subadult female
1899	W. center, Four Mile Lake; May 27, 1943; 25 days	W. center, Four Mile Lake; Nov. 19, 1943; same vicinity	507 mm.; 770 g.; 201 days	Subadult male testes, 8×5×3, mm.

The back-tagging method still seems the best of any yet described for marking young muskrats after the first week of life and up until weaning time, the ages at which they are easily captured by hand from marsh lodges. Differences in the visibility of tags in the fur of subadult muskrats obtained from trappers are shown by specimens in the foreground of Plate 16, A. Other tags in the background are held up under tension by strings, to demonstrate the strength of the skin by which they are attached.

Personal observations on the propensity of at least young Iowa animals to scratch or gnaw tags caused me to doubt that tagging would be efficacious unless the tags were placed as nearly out of reach as possible; even those fixed to skin between the shoulders often showed tooth marks upon later recovery (Plate 16, B). The lack of chewing implied by Takos (1943:405) in reporting his experience with Arthur Cook's method of fastening a tag about the Achilles tendon (where it certainly should be accessible to the muskrat) was therefore surprising. Back-tagging gives scant promise for marking muskrats more than a month old and the

advantages of the Cook method, so far shown, are sufficient to make it seem the outstanding one yet tried on older and larger individuals. Other techniques, such as ear-tagging with monel metal fingerling tags (see Scott, 1942, for successful use on mice), remain to be investigated further. Less abrasion might be expected for ear tags retained over long periods than for those on the hind legs of a species having the general habits of the muskrat.

SUMMARY

Since the results of preliminary work in back-tagging of 463 young (mainly suckling) muskrats in Iowa were published in 1937, 214 additional individuals marked similarly; of the latter, 17 were again handled or heard of after intervals sufficient to give valuable data. Sixty-five other young muskrats were toe-clipped, making a total of 742 marked by all methods from 1935 to 1943. Due to the severity of drought emergencies, only one toe-clipped specimen was later recovered.

In view of the known evidence, the back-tagging method appears, under natural Iowa conditions, to be highly effective when used exclusively for the marking of muskrats in the second to fourth weeks of life, the ages when often obtainable in large numbers from marsh lodges. This method, however (tried without success by Takos in Maine on mixed age classes, living in polluted waters), is not recommended for marking muskrats more than four weeks of age.

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SUMMER MOVEMENTS OF BANDED MUSKRATS[1]

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The movements of tagged muskrats (*Ondatra z. zibethica*) were studied on a marsh in central Maine during 1941 to determine the distances that individuals wandered over the area. The animals were taken in box traps, tagged by techniques described in a previous paper (Takos, 1943), and then released. A total of 107 were banded and 40 were recaptured one or more times. The present paper is based on the records of the 40 repeating individuals.

Trapping extended from April until October and was almost continuous during June, July, and early August. Otherwise the traps were set for several days at a time at approximately biweekly intervals. Operations were confined to part of the East Branch of Sebasticook River between Corinna Village and Sebasticook Lake. It lies within Newport and Corinna townships in Penobscot County. Known locally as Corinna Stream, this area includes about 120 acres of cattail marshes and three and a half miles of sluggish, winding streams. Plants most frequently eaten by muskrats were abundant, predominantly cattails and sedges.

The literature, in general, agrees that each muskrat typically lives within a restricted home range. From observations of the activities of individuals inhabiting isolated small ponds and marshes, Seton (1937) concluded they rarely wander more than 200 yards from their homes. Errington (1939) writes that "... the tendency appears ... for muskrats to remain in much the same sections of a given marsh or stream during summer, fall, and winter." Despite this trend, periods of wandering in the spring and autumn have been noted frequently, usually in densely populated areas or during periods of drought. The Erringtons (1937) recovered tagged individuals at 3 to 21 miles from the banding sites. Populations sometimes tend to drift into favorable muskrat-vacant habitats, especially in regions where the species has been introduced. The European literature reports several invasions of "virgin" territory by animals which escaped from colonies (Ulbrich, 1930; Warwick, 1934); and similar occurrences have been noted in the United States when access was obtained across natural barriers into regions where the animals were previously unknown (Storer, 1937). Likewise, wherever muskrats are native, they tend to reoccupy areas from which the indigenous population has disappeared (Errington, 1940). These facts, however, do not invalidate the general tendency of individuals to remain within a limited area.

Methods

Baited box traps of two kinds were

[1] Contribution from the Maine Cooperative Wildlife Research Unit, Orono, Maine. Maine Department of Inland Fisheries and Game, University of Maine, American Wildlife Institute, and U. S. Fish and Wildlife Service, cooperating. John Pearce gave numerous suggestions and criticisms as to methods, and Howard L. Mendall offered valuable advice during preparation of the manuscript.

used, one of wood and operated on the "false-bottom" principle and the other of wire-mesh and closed through the action of a trigger mechanism attached to a bait chamber. Sets were made in runways, at landing places, on feeding platforms, or on specially constructed rafts, and pieces of apple and carrot were used for bait. Six to ten traps were usually operated at any one time. Sets were made at trapping stations for five successive nights and then moved to new locations unless untagged animals were still being captured. The traps were every time immature animals were taken.

Trap locations were marked on a base map previously prepared by plane-table survey, and distances between trap sites were determined by chaining or pacing. Detailed maps of small sections of the area were prepared in the field during the low water in late September and October.

RESULTS

The site of first capture and tagging was arbitrarily used as a focal point, to

TABLE 1.—MUSKRATS CAPTURED TWO OR MORE TIMES.
(April 12 to October 20, 1941)

	Individuals	Times captured	Times captured at various trap sites							
			Original site	Within 25 ft.	25–50 ft.	50–75 ft.	75–100 ft.	100–125 ft.	125–150 ft.	150 ft. or more
Males	17	84	34	7	5	7	7	12	—	12
Females	14	72	32	12	2	5	1	6	1	13
Immatures[a]	9	28	22	1	2	2	1	—	—	—
Totals	40	184	88	20	9	14	9	18	1	25

[a] 8 males, 1 female.

spread over the study area to insure uniform sampling of the population.

With one exception (No. 2) each muskrat captured was released at the trap site after tagging. Records were made of the date, weight, signs of sexual activity, type and location of trap, and the type of set each time an animal was captured. For each muskrat tagged note was made of the sex, length of tarsus, length, width, and height of tail, and any peculiarities which might aid in later identifying the individual. These latter data helped with individuals which lost their tags. The weight and the measurements were recorded which subsequent captures were related, and the distances to the various traps where the animal was recaptured were considered as emanating radii. This concept involves some error, especially when the place of first capture was not near the center of the animal's home range. It did, however, provide a consistent way to handle the data, since there was no means of definitely associating an animal with a particular lodge or bank burrow, and a reference point had to be established.

The number of recaptures and the distances from points of original capture are summarized in Table 1. In

about half of the instances, individuals were recaptured at or within a 25-foot radius of the banding site, and about 70 per cent of the repeats were within a 100-foot radius. The tendency to remain in a locality was most pronounced in sexually immature animals, all of which were recaptured within 100 feet of the focal point. This was noted previously by the Errington (1937). In view of the limited data available, no conclusions were drawn as to the possible relation between sex and the distances traveled.

A different type of attachment to the home range was demonstrated by No. 2. It was caught along Corinna Stream on April 12, and released the next day deep in a cattail marsh about one-fifth mile further north. About three weeks later it was recaptured within 75 feet of the initial trap location, and on May 4, was recovered at the original site, over 320 yards from where released. The animal was an adult female with no signs of pregnancy or recent parturition when first taken, and there is no obvious reason why it did not remain where released.

TABLE 2.—RECORDS OF INDIVIDUAL MUSKRATS CAPTURED 5 OR MORE TIMES.

Muskrat number	Age and sex	Times taken	Dates of first and final capture	Times captured at various trap sites										Maximum distance in feet between points of capture
				Original site	Within 25 ft.	25–50 ft.	50–75 ft.	75–100 ft.	100–125 ft.	125–150 ft.	150–175 ft.	175–200 ft.	200 ft. or more	
26	Ad. ♀	9	5/24– 7/ 3	7*	2	—	—	—	—	—	—	—	—	25
35	Ad. ♀	6	6/30– 7/18	2	—	—	3	1*	—	—	—	—	—	80
42	Ad. ♀	6	7/13– 7/21	1	5*	—	—	—	—	—	—	—	—	20
60	Ad. ♂	28	4/20– 8/ 7	1	—	2	3	—	11*	—	5	—	6	260
65	Ad. ♀	13	7/19– 9/ 5	11	—	—	—	—	—	—	—	—	2*	210
71	Ad. ♀	14	7/ 1– 8/ 1	2	2*	—	—	—	1	—	1	8	—	185
75	Ad. ♀	5	8/ 6– 8/19	1	1	1*	—	—	—	—	—	—	2	265
78	Ad. ♀	5	7/14– 9/ 8	3	1	—	—	—	—	1*	—	—	—	140
83	Imm. ♂	7	9/ 4–10/20	6*	1	—	—	—	—	—	—	—	—	20
93	Ad. ♀	5	9/10– 9/18	1	—	—	1*	—	3	—	—	—	—	120
94	Ad. ♂	5	9/10– 9/15	4	—	—	1*	—	—	—	—	—	—	55
98	Ad. ♂	6	9/11– 9/21	1	3*	—	—	2	—	—	—	—	—	110

* Final capture.

Details for all animals taken five times or more are presented in Table 2. These records are self explanatory for the most part, and, as might be expected in a small sample, considerable variation is shown. No. 65 was captured 13 times in all, 11 times at the original trap site. Subsequently it was recaptured twice along Corinna Stream about 210 feet from the original site. The marsh had dried out where the muskrat lived previously, forcing the animal to quit its home territory. Errington (1939) reports similar withdrawals from drought areas.

The wanderings of No. 60 furnished the most complete series of data (Fig. 1, *A* to *J*, are trap sites where taken). Site *A*, the place of first capture, was near the periphery of its range. The greatest straight-line distance between succeeding captures was 260 feet. Eight other muskrats also were taken within the area occupied by No. 60, chiefly at stations *D*, *E*, *G*, and *J*, but were not recaptured enough times to determine the degree of overlapping of their ranges.

The maximum distance between points of capture was with No. 76, an adult male. On August 10 it was in a trap at station *K* and the next morning was recaptured in a box trap on a raft in Corinna Stream at site *L* (Fig. 1); these locations were 570 feet apart. Previously it had been trapped once

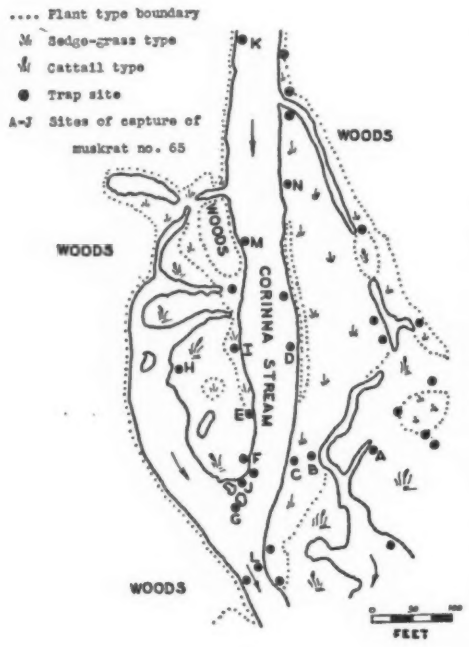

Fig. 1. Trapping stations on Corinna Stream Study Area, Penobscot County, Maine.

each at stations *M* and *N*. It was not retaken after August 11, but this limited record indicates that some individuals may have more extensive territories than others. Several adults of both sexes showed similar tendencies to range widely.

Tabulation of the data was premised on recapture of a fair number of the animals tagged; about 37 per cent of those banded were retaken, but it is impossible to account for the 67 animals not retaken. Perhaps some were excluded from the traps by the previous capture of muskrats or other animals—frogs, turtles, and various birds were frequent offenders. Others may have wandered from the vicinity, or the traps may have been lifted before the animals could repeat, and some probably died.

SUMMARY

Movements of tagged wild muskrats in Corinna Stream, Maine, were studied by recapturing individuals at frequent intervals throughout the spring and summer of 1941. Of 107 banded, 40 were recaptured for a total of 184 times. Most of them tended to remain near the area where banded, about 50 per cent of recaptures being within a 25-foot radius of the original banding site and less than 30 per cent beyond a 100-foot radius. All banded immatures recovered were within a 100-foot radius. One animal returned to the station where originally taken, although released over 320 yards distant. Most of the animals remained within a limited home range, but a few tended to occupy more extensive territory.

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ROLE OF TICKS IN DECLINE OF AN INSULAR COTTONTAIL POPULATION[1]

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The irruptive behavior of lagomorph populations when freed from certain of their environmental controls has been of economic concern to man since early times, particularly when rabbits or hares have been transported to new countries or to islands.

The European rabbit (*Oryctolagus cuniculus*), indigenous to North Africa and Spain, was distributed around the Mediterranean by the Romans. In 50 B.C., Strabo recorded prayers of the inhabitants of Sardinia and Corsica for relief from the animals, which had become a pest. Carried to England by the Plantagenet kings, rabbits remained scarce for several centuries before increasing to plague proportions (Jennison, 1927). Recently, Lockley (1940) reported an irruption of the species on Skokhol Island, Pembrokeshire, Wales. Two dozen European rabbits, released for sport in Australia in 1859, initiated a world-famous irruption and produced a problem for which no really successful control has been discovered (Stead, 1935).

In the United States irruptions have been recorded following introduction of the red hare (*Lepus europaeus*) in the Hudson and Connecticut river valleys (Silver, 1916), and of the European rabbit in the San Juan Islands, Washington (Couch 1930). Records of similar results with cottontails in this country are few, although Barbadoes Islands, Pennsylvania (Cramer, 1940) seems to have been the site of such an overpopulation.

The present report deals with the cause of decline of an introduced cottontail population exhibiting irruptive behavior on Fishers Island, New York. This island, of about 3,600 acres, lies about two miles offshore from New London, Connecticut. Since the cessation of grazing there in 1924, much of the open land has been overgrown by

[1] Joint contribution of Supplements B and E, Pittman-Robertson Wildlife Restoration Project 1-R, New York State Conservation Department.

bayberry, blackberry, black cherry, elderberry, greenbrier and shadbush. The principal native grasses belong to the genera *Andropogon, Panicum, Spartina, Cenchrus,* and *Ammophila.* Woodlots contain black oak, sour gum, beech, and red maple. The development of summer residences and golf courses has involved the planting of bent grasses, blue grasses, and fescues. Greenbrier (*Smilax rotundifolia*) provides excellent cover and some food for pheasants, quail, and rabbits.

Excavation of Indian middens and of burial mounds have unearthed the bones of moose, deer, red fox, otter, mink, beaver, woodchuck, and muskrat (Ferguson, 1935); the last is the only one of these still present. Besides the muskrat, the existing mammals include the Norway rat, house mouse, cat, grey squirrel, 13-lined ground squirrel, and cottontail—all introduced. The ground squirrel and cottontail were imported from the Middle West.

Remains of ruffed grouse also were found in the middens, but none of these birds has been seen for many years. Stocking with pheasants, turkeys, bobwhite quail, Chukar partridges, and Hungarian partridges has met with indifferent success; only the ring-necked pheasant has increased, bobwhites barely hold their own, and the others have disappeared.

Prior to 1914 an attempt was made to stock the island with European rabbits. Contrary to expectation, they barely held their own and then disappeared about 1928. About 1925 several dozen cottontails of midwestern origin (probably *Sylvilagus floridanus alacer*) were liberated. Some died soon afterward but the species became established and in the absence of ground predators, increased so rapidly that by 1938 damage to lawns, golf courses, and shrubbery had become serious. A bounty of 20 cents per pair of ears during the 1938–39 winter resulted in the destruction of over 3,000 rabbits, but this did not solve the problem. Approximately 1,200 rabbits were killed the following winter when there was no bounty inducement, but removal of these brought no noticeable reduction in the cottontail population.

In September, 1940 the problem of control was brought to the attention of the New York State Conservation Department by Mr. H. L. Ferguson of Fishers Island Farms, Inc. Investigation showed that there was an estimated population of about 10 rabbits per acre and that the animals had damaged lawns, gardens, and shrubbery severely. Rabbits then collected were in good condition, although carrying many immature ticks (identified by Dr. R. R. Parker as *Haemaphysalis leporis-palustris*) and moderate numbers of fleas. One immature rabbit showed a mild case of coccidiosis.

In March 1941 Department representatives, undertaking the live trapping and transfer of several hundred rabbits from the island, found all of the rabbits in poor condition and picked up several each day, which had died from starvation. The following winter (1941–42) when trapping was resumed, the population was somewhat reduced but the remaining animals were in good condition. In the late summer and autumn of 1942, residents reported many dead rabbits, all heavily parasitized by ticks. No rabbits were live-trapped that winter.

The authors investigated conditions on the island between May 11 and 20, 1943. Examination of the vegetation showed far less damage caused by rabbits than was observed in March 1941, indicating that the rabbits could not have reached a starvation level during the winter of 1942–43. The population was estimated to be not more than one per four acres, and was unevenly distributed.

It soon became evident that a considerable mortality was occurring among all age classes of the rabbits. Because of a delayed insect season and the absence of scavengers, it was possible to find remains of 119 cottontails, 42 of of which were judged to have died within a month; of these, 8 adults and 2 young were picked when quite fresh, 2 young had been drowned, and 4 adults had been killed accidentally. The remaining 26 were in various stages of decomposition. All showed signs of heavy parasitization by ticks; all live rabbits seen at close range were observed to be similarly parasitized by engorging ticks and many obviously were in poor condition.

Autopsies were performed on 33 cottontails: the 8 adults and 2 young found dead and 21 adults and 2 young collected by shooting. One juvenile, caught by hand, was examined for ticks and liberated. The 29 adults revealed the following incidences of internal parasites:

Intestinal fluke (*Hasstilesia tricolor*)	1 (3%)
Rabbit tapeworm (*Cittotaenia* sp.)	10 (34%)
Dog tapeworm larvae (*Taenia pisiformis*)	11 (38%)
Stomach worms (*Obeliscoides cuniculi*)	20 (69%)
Pinworm (*Dermatoxys veligera*)[2]	22 (76%)
Nematode (*Trichostrongylus calcaratus*)[2]	11 (38%)

All of the rabbits were examined for gross lesions of coccidiosis but none was found. None of the internal parasites encountered was considered to be of pathological importance. Of the 4 juvenile rabbits examined, two had light infections of *Obeliscoides* and one a light case of coccidiosis. No other internal parasites were encountered.

Ticks were the most abundant and the most important parasites. Counts on the 34 rabbits showed a total of 1,377 (adults, 661; nymphs, 716). Of 571 ticks brought to the laboratory at Delmar for examination, 397 were *Ixodes dentatus*[2] and 174 were *Haemaphysalis leporis-palustris*, the common rabbit tick. Adult ticks and abandoned points of attachment on collected rabbits averaged 18.9 as compared to 64.6 on rabbits found dead. A similar comparison for tick nymphs could not be made, since they abandon the bodies of rabbits dead longer than three or four days. Ticks partly engorged at the time of death of a rabbit seemed unwilling or unable to release themselves, so that many perished with decay of the carcass.

The 10 dead rabbits satisfactory for autopsy bore heavy infestations about the neck and ears of 20 to 120 engorging ticks. The pathological conditions noted most consistently were anemic condition of the lungs and kidneys, pale, watery appearing blood, and many small pus pockets at the sites of tick attachment.

Anemia associated with the presence

[2] Identified by Dr. G. Dikmans, Zoological Division, Bureau of Animal Industry, U. S. Department of Agriculture.

of many engorging ticks also has been observed in domestic rabbits parasitized by *Dermacentor andersoni*. Jellison and Kohls (1938) were able to demonstrate experimentally that 80 or more female *D. andersoni*, engorging normally, could kill a rabbit in five to seven days.

Of the 8 adult cottontails found dead, 4 had abscessed or swollen lymph glands, indicating spread of infection from the small subcutaneous abscesses at the points of tick attachment. There was always hyperemia and edema of the skin in the neck region occupied by the ticks; this congestion and swelling was more severe among the rabbits found dead than among any of those collected by shooting.

Only 2 of the 8 rabbits showed evidence of mechanical injury as a cause of death. Autopsy of one rabbit (brought in by a dog) showed no mechanical injury sufficient to cause death; and it is probable that the dog found the specimen dead. The rabbit had 75 ticks still attached on the back of the neck, was emaciated and anemic, had many abscessed points of attachment, and the right submaxillary lymph node was abscessed. This animal was as gravely diseased as the most severely affected of those found dead without either historical or autopsy evidence of mechanical injury. The second rabbit, likewise gravely ill before death, showed mechanical injury resulting in a ruptured stomach and blood free in the body cavity. It also was heavily parasitized by ticks, with numbers of their attachments abscessed, and with metastatic infections of the submaxillary nodes and of the left kidney, which had been completely destroyed. The 2 juveniles showed, in addition to the ticks and the infected points of attachment, anemia only.

The 21 adult and 2 juvenile rabbits collected by shooting were all parasitized by ticks with the usual pathology of white-cell reaction at the points of attachment, plus numerous foci of bacterial infection. In 5, infection had spread by metastasis from these foci to nearby lymph nodes and, in one, to the pericardial sac and heart muscle; the sac was filled with purulent material and its membranous wall greatly thickened. The infection had made shallow penetration into the myocardium. No lymph nodes were affected, but there were two subcutaneous abscesses, one behind the right ear and the other at the point of the left shoulder. This rabbit was nursing young and also was carrying five normal embryos; she weighed 1,220 grams, of which 80 grams was that of the gravid uterus. The other four cases of metastasis included one with an abscessed right cervical node about 12 mm. in diameter, 2 with swollen right axillary nodes, and one with swollen submaxillary nodes.

Of the 18 rabbits not showing metastatic infections, all but two had small subcutaneous abscesses from 6 to 25 mm. in diameter which were almost invariably associated with the presence of adult ticks or the sites of former attachments. Nymphal ticks were generally distributed over the body, but in no case was there an abscess that seemed directly associated with their presence.

From the nature of the lesions, pigment-producing staphylococci were in-

dicated; but facilities for bacteriological analysis were lacking. Bell and Chalgren (1943) found *Ixodes dentatus* ticks apparently involved in the production of pyogenous infections among cottontails in Pennsylvania. In support of their belief that the infections may have been tick-borne, they cite the occurrence of "tick pyemia" among lambs in Scotland, as well as their own observations on the apparent connection between feeding points and occurrence of skin infections. Previous studies in New York State (Cheatum, 1941), on what has been called "lymphadenitis" in cottontails, did not show any connection with tick parasitization, since infections appeared to stem from skin injuries sustained while occupying swampy cover in winter. Observations made during attempts to rear cottontails in large ground pens in New York State have revealed similar infections developing from skin injuries, in the complete absence of ticks. Our experience on Fishers Island is apparently comparable to that of Bell and Chalgren in Pennsylvania; but whether ticks transfer the bacterial infection from one rabbit to another is yet to be demonstrated.

In checking on the relationship of the nesting period to the decline, we located 5 active nests, 7 successful nests, 3 unnsuccessful nests, and 2 litters just out of the nest. Of the 5 active nests, 2 were ultimately unsuccessful because the mothers failed to return. The cause of this apparent desertion was suggested when 2 females, picked up dead elsewhere on the island, were found to have been nursing. From the other 3 active nests, one litter departed successfully and the others were about to do so when the study was terminated. There were 5 young in one litter; the others contained 4 each. These litters and the average number of embryos (4.3) found in pregnant females indicate no decline in the number of young per female. A few *Haemaphysalis* in the nymph stage appeared on one litter of nestling rabbits as early as 48 hours after birth, and on all nestlings by the ninth day.

Of the two litters found after leaving the nest, one consisted of at least two young found drowned in a lily pool about 15 feet from a successful nest. They were apparently just out of the nest and had been dead about a week, yet still bore living *Haemaphysalis* nymphs. The second litter, about two weeks older, consisted of at least three, only one still alive, and all were heavily parasitized by engorging *Ixodes*.

Two gray squirrels, one ground squirrel (*Citellus*) and one muskrat were livetrapped and examined for ticks, but the results were negative. Two pheasants, one having the right eye closed, were observed to have heavy loads of engorging ticks about the head. Reports from the previous hunting season indicated considerable parasitism by ticks on pheasants, but without observed mortality. No specimens of the ticks parasitizing pheasants were obtained for identification. Hunting dogs on the island were reported to bear an occasional tick.

A return visit in mid-September, 1943, revealed no signs of *Ixodes* on either cottontails or pheasants and none of recent mortality among the cottontails. Of 57 rabbits seen, five had bare

spots and scars on the neck presumably from previous tick attachments. Only one that could be classed as juvenile was seen. All evidence indicated that there were far fewer rabbits than were present during May, but that those remaining were in good condition and still abundant enough to be considered a nuisance.

DISCUSSION

The above evidence indicates that the immediate cause of the observed mortality among these cottontails was tick-induced anemia, with *Ixodes dentatus* primarily responsible. Infections spreading from tick attachments undoubtedly hasten death, but experience elsewhere has shown that these alone are not usually fatal. Two cases of recovery by captive cottontails from subcutaneous abscesses have been observed.

"Tick paralysis" is a possible cause of mortality that cannot be disregarded entirely, because no rabbits were found just before death. This has been associated with engorging female ticks, *Dermacentor andersoni* in the western United States and *Ixodes holocyclus* in Australia. The meager evidence, however, is against such a possibility for the stomachs of recently dead animals contained food and the position of the bodies indicated convulsive movements at the time of death rather than paralysis; also the live rabbits heavily infested with ticks gave no signs of being paralyzed. (Two rabbits were found dead on lawns that had been free of rabbit carcasses the previous evening.)

At what level the drastic reduction in rabbit numbers will cease cannot be determined. A smaller population would be welcome by the residents of the island for, unless the cottontails are exterminated, they will always cause some damage by concentrating around cultivated lawns and gardens.

The possible effect of similar parasitism on the pheasant population seems to be of no great concern, because an adequate annual stock for shooting and for field trials is ensured by the preseason liberation of purchased birds.

SUMMARY

Fishers Island, New York, was stocked with several dozen midwestern cottontails about 1925; in the absence of ground predators, overpopulation resulted and there was serious damage by 1938. Attempts at control by bounties and by shooting were unsuccessful. Following moderate reduction by winter starvation in 1940–41, a considerable mortality accompanied by tick infestation was reported in 1942.

Investigation in May 1943 showed a substantial mortality through parasitization of adult rabbits by *Ixodes dentatus* and, to a lesser degree, by *Haemaphysalis leporis-palustris*. Apparently death was caused by (1) tick-induced anemia; or (2) bacterial infections at points of tick attachment which resulted in localized or metastatic pyogenic infections of the lymph nodes. Juvenile losses occurred (1) when nestlings were abandoned by sick or dying female rabbits, or (2) when burdened with fatal infestations of ticks after leaving the nest.

The local pheasants were parasitized by ticks but not killed thereby, so far as is known. One muskrat, two grey squirrels and a ground squirrel were free of ticks when examined.

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SUPPLEMENTAL WINTER FEEDING OF MULE DEER IN NORTHERN UTAH[1]

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Certain big game species in Utah and other states rapidly recovered during the past 30 years from the low numbers existing before the advent of enforced hunting regulations. This has resulted from several factors, important among which are the establishment of refuges, protection of females, and control of natural enemies. Meanwhile much of the human population has become "game minded" and believes that wild game must be protected and increased.

The greater numbers of big game have increased management problems; failure to recognize definite limits to maximum game populations frequently has led to various difficulties. The importance of recognizing and maintaining a proper balance between big game and its range forage has not been accepted generally until recent years.

Winter range problems for game in Utah first became acute in the northern part of the state due to the severe weather and restricted range. As an initial corrective measure, the Utah Department of Fish and Game in 1931–32

[1] Utah Department of Fish and Game, Utah State Agricultural College, American Wildlife Institute, and U. S. Fish and Wildlife Service, cooperating. At North Logan, Albert Beck did the feeding during the entire study and aided in the field observations. The following students conducted winter studies: Nathan Snyder, 1934–36; Jay L. Sevy and Max Bridge, 1936–37; T. B. Evans, 1937–38, and J. J. Nemanic, 1941–42. Members of the Utah State Department of Fish and Game, U. S. Forest Service, college faculty, and numerous students assisted in the winter surveys, censuses, and routine work. R. J. Costley, U. S. Forest Service, supplied detailed field surveys of numbers and losses during 1938–39.

spent $3,000 to protect private property from elk damage and to feed elk in winter on ranges adjacent to the Cache National Forest.

Mule deer in several areas have increased until they exceed the grazing capacity of their winter ranges and have depleted the native forage plants; many have died from malnutrition and related causes. Landowners complain when the deer invade cultivated fields, orchards and haystacks during the winter and early spring.

The feeding of hay to supplement native forage was initiated on some concentration areas of northern Utah as an emergency measure during winters of heavy snowfall in the belief that this would keep the big game animals from dying of starvation, prevent them from invading private lands, and relieve pressure on the native forage. In most places, however, the adjacent winter range became depleted and the deer concentrated on such areas in increasing numbers until feeding became a common practice and seemed necessary every year. Such feeding did not prevent large losses on the depleted ranges during average winters, but was generally believed to be the "cure-all" and the humane thing to do. Close observers became skeptical of the value of feeding, because similar losses did not occur on adjacent ranges having adequate native forage. There was definite need to learn what was happening and to seek improved diets and feeding methods, particularly where natural winter range was less than the summer range and apparently was the factor limiting the game herd.

Preliminary studies on use of winter supplements for mule deer were begun on northern Utah feed-grounds in 1935–36 by the Utah Cooperative Wildlife Research Unit. In 1940, these were expanded to include penned deer at the Cache Experimental Area under a Federal Aid Project (Utah 8-R; and 17-R) in cooperation with the Research Unit —these studies were continued until April, 1943.

During 1941 and 1942 12 diets employing various native browse were fed to an average of 16 penned mule deer in central Utah; a report on these studies is in preparation.

HISTORY

CACHE EXPERIMENTAL AREA

The Cache Experimental Area, 3 miles northeast of Logan, between the mouths of Logan and Green canyons, borders the foothills and the Cache National Forest at an elevation of 4,900 feet. It comprises 120 acres of sagebrush and dry-land alfalfa, including the North Logan feed-grounds, and was purchased by the Utah Department of Fish and Game in 1939. In 1940, a deer fence was built along the lower boundary and four holding pens, traps, and an equipment building were constructed. The purchase and development were financed by the Federal Aid in Wildlife Restoration Act. The only subsequent livestock use has been by deer.

Large winter deer congregations were first reported on the adjacent area (Logan-Green Canyon) about 1930. From the spring of 1931 until 1933 the state hired herders to keep deer from invading private cultivated fields and orchards, but the attempts were unsuccessful and damage continued. These difficulties, and malnutrituion in the

deer, led to a small-scale feeding program late in January, 1934, using alfalfa hay.

A few deer reportedly had died during "hard" winters, but there was no record of excessive losses until 1935–36. The herd had increased steadily since first estimated in 1917 (Table 2) but not unduly in 1935. The heavier than average snow during 1935–36 forced more of the larger herd to the lower winter ranges, already depleted during several previous winters. In 1935–36 there was not enough native forage to supply the needs of the increased herd, and supplemental feeding of alfalfa did not prevent heavy losses.

Tagging studies showed this area to be a natural terminus in deer migration from the entire Logan Canyon drainage that extends northeastward 35 to 40 miles and to nearly 10,000 feet in elevation (Fig. 1). These deer summer on an extensive ideal range not overpopulated, but the large herd on a limited winter range brings abnormally concentration on the latter.

The deer that use the North Logan feed-ground regularly, range during the winter on steep mountain sides where the elevation changes 2,000 feet within the first mile. This wintering area extends from about one-half mile north of Green Canyon to Logan Canyon and up Green Canyon for about three-quarters of a mile; it is a fairly distinct unit comprising about three square miles, but during some winters the available part is much restricted by deep snow at the higher elevations and on north facing slopes. Ordinarily the deer move to the feed-grounds in late afternoon or evening and return to this area during the night.

Over-grazing of the palatable native forage species was obvious on the Logan-Green Canyon area as early as 1934–35, with a definite over browsed high-line in evidence on the junipers (*Juniperus utahensis* and *J. scopulorum*) and curlleaf mahogany (*Cercocarpus ledifolius*). Bitterbrush (*Purshia tridentata*), birchleaf mahogany (*Cercocarpus montanus*), and staghorn sumac (*Rhus cismontana*) were heavily utilized and hedged. On all except the junipers, reproduction was eaten to the ground. Sagebrush (*Artemisia tridentata*) was used moderately, but showed no evidence of over grazing.

Each year since 1936 there has been further decline in the more palatable browse species until by 1943 they were producing little new growth. During the past two years only the sagebrush produced a significant quantity of forage. It is now heavily over-grazed. Within a quarter mile radius of the feed-ground the new annual growth is only about 25 per cent of former production and about half of the plants have been killed; within a half mile the estimated reduction is 50 per cent and within a mile is 25 per cent. This species has been greatly reduced in vigor over the entire area and is being over-grazed at further distances from the feed-ground each year. Species of very low palatability such as maple (*Acer grandidentatum*) and rubber rabbit-brush (*Chrysothamnus nauseosus*) now show heavy use. During this same period the native grass cover on areas used only by deer has increased, primarily the bunch wheatgrass (*Agropyron spicatum*) and species of bluegrass (of which *Poa secunda* and *Poa longiligula* are most abundant).

Following inauguration of the feeding program, stomach analyses of deer killed on or near the feed-ground showed increasing dependence on supplemental feed and during 1941–42 and 1942–43 sagebrush alone provided

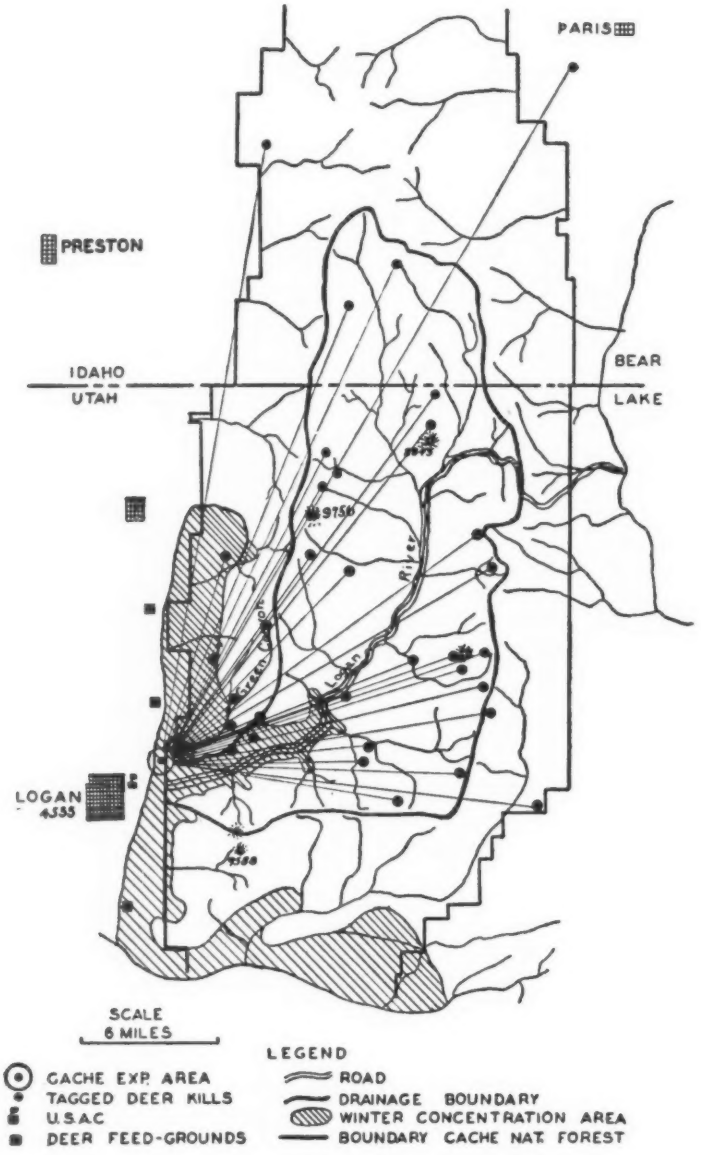


Fig. 1. Logan River Drainage and adjacent range, Utah, showing returns from mule deer trapped and tagged at the North Logan feed-ground in winter and subsequently shot during regular hunting season in late October. Elevations of a few places given in feet above sea level.

TABLE 1.—PERCENTAGE CONTENTS OF DEER STOMACHS (10 PER YEAR) FROM NORTH LOGAN FEED-GROUND AREA.

Winter	Sage-brush	Other native forage	Supple-ments
1940–41	*16.4*	*23.8*	*59.8*
1941–42	*13.3*	*4.1*	*82.6*
1942–43	*11.0*	*4.0*	*85.0*

any significant amount of natural feed (Table 1).

DEER HERD

Estimates of the numbers of deer and of the kill by hunters on the Utah Division of the Cache National Forest were compiled from records of the U. S. Forest Service (Table 2). Our field surveys in 1935–36 indicated that these estimates were low. Intensive studies on portions of this Forest, including the Logan River drainage and the area from the mouth of Logan Canyon north to Idaho, were made by the authors from 1935 to 1943. This portion is estimated to contain approximately two-thirds of the deer on the Utah Division. Our field surveys, spot counts, and tagging studies, together with data from hunter checking stations, are the basis for the data on recent populations and removals (Table 3).

The first known heavy losses occurred in March and April 1936; a careful survey of the lower foothills on the Logan-Green Canyon area (April 1936) revealed 123 dead deer, of which 114 were considered to have died directly from

TABLE 2.—ESTIMATES OF DEER NUMBERS AND KILLS ON CACHE NATIONAL FOREST (UTAH DIVISION).

Year	Population	Bucks killed
1917	250	9
1918	425	—
1919	—	28
1920	425	40
1921	450	—
1922	450	13
1923	315	—
1924	350	—
1925	456	40
1926	500	22
1927	620	45
1928	1,370	107
1929	1,750	68
1930	1,900	97
1931	2,074	98
1932	2,382	86
1933	2,624	365
1934	3,500	675
1935	3,800	574

TABLE 3.—DEER IN UTAH ON LOGAN RIVER DRAINAGE AND NORTH TO IDAHO, 1936–43; BASED ON FIELD SURVEYS, SPOT COUNTS, AND HUNTING REMOVALS.

Year	Estimated population Jan. 1	Utah removals		Total[a] recorded kill Utah and Idaho	Estimated losses from malnutrition
		Bucks	Antlerless deer		
1936	4,700	419	0	469	600[b]
1937	4,500	370	0	420	75
1938	5,200	453	81	584	25
1939	6,000	675	508	1,233	1,000
1940	5,000	517	347	914	50
1941	5,000	621	501	1,172	25
1942	5,000	528	491	1,069	500
1943	4,500				600

[a] An estimated 40 to 60 more are killed legally in Idaho under a law that permits taking one of either sex. Tagging shows that these deer winter in Utah, hence they are included in the January population estimates.

[b] Includes losses of winter and spring, 1935–36.

malnutrition; 80 per cent were fawns 9 to 10 months of age.

In the long winter of 1938–39, deer were forced to the lower ranges early in December and held there by heavy snows until April. An estimated 1,000 from the Logan Canyon herd died from malnutrition following late snow storms in March.

In October 1939, 1,000 permits were issued to kill antlerless deer on the Cache Forest in Utah; also a former refuge of 50 square miles, south and east of the mouth of the right hand fork of Logan Canyon, was opened to hunting. The recorded kill in 1939 on the Logan River drainage and north to Idaho was 1,183 and included 508 antlerless deer. This was larger than recorded in any previous or subsequent year; coupled with the enormous losses of the previous winter, it effected a material reduction, and studies in 1940 indicated a population of about 5,000. Hunting removals and winter losses held the numbers nearly stable from 1940 until 1942, but additional losses from malnutrition and heavy hunting in 1942 decreased the population in 1943.

Winter counts and estimates for that portion of the Logan-Green Canyon winter range from which deer move daily to the feed-ground have been made annually from 1936 to 1943; they varied from 550 in 1937 to 1,320 in 1939, the average being 915. The maximum count on the feed-ground in any one day varied from 869 in 1939 to 215 in 1941, and the average number fed per day varied from 600 in 1939 to 150 in 1938 (Table 4).

TABLE 4.—ARTIFICIAL WINTER FEEDING OF UTAH MULE DEER ON NORTH LOGAN FEED-GROUND.

Year	Estimated number, Logan-Green Canyon area	Number of deer fed		Supplemental feed (tons)	Period of feeding	Total winter losses	Remarks
		Maximum	Average				
1935–36	1,050	580	250	15, alfalfa	Jan. 28–Mar. 16	140	Winter severe; most losses after heavy snow storms in late March and April.
1936–37	1,000	829	400	20, alfalfa	Jan. 10–Mar. 10	30	Winter open, spring early; only about 20 deer remained by March 10.
1937–38	550	—	150	6, alfalfa	Intermittent, 50 days	10	Winter open; little snow.
1938–39	1,320	869	600	41, alfalfa 6, pea silage	Nov. 26–Apr. 6	310	Deep snow at low elevations; most losses after late snow storms in March and April.
1939–40	900	458	300	26, alfalfa	Jan. 16–Mar. 18	15	Winter mild; deer fed in Green Canyon and North Logan.
1940–41	750	215	200	14, alfalfa	Jan. 5–Mar. 12	10	Winter open, little snow.
1941–42	900	619	400	40, alfalfa	Dec. 28–Mar. 25	150	Winter average; heaviest losses, March 16 to 28.
1942–43	800	659	400	33, alfalfa 2, barley 2, sheep pellets	Jan. 7–Mar. 24	175	Winter open on lower range. Deer had access to north slopes all winter. Ninety five per cent of losses after March 1.

SUPPLEMENTAL FEEDING 1934–40

Feeding of alfalfa hay began on the North Logan feed-ground in January 1934 (see "history," above), and has

continued each winter since then. The deer have been given all the alfalfa they would consume, and various other supplements have been tried (Table 4).

Accurate records of the number of deer on the feed-ground and amounts of hay used are lacking for 1933–35; an estimated five or six tons were fed in 1933–34 and 10 tons in 1934–35. Considering the average number on the feed-ground from 1936 to 1939, the feed averaged slightly over one pound per animal per day. From 1940 to 1943 the daily consumption of supplements has been over two pounds per deer per day.

On the basis of the feeding of supplements here reported and the experimental feeding of native forage, a maintenance ration for mule deer in Utah is slightly over three pounds of air dry forage per hundred weight per day and slightly over four pounds daily per average deer (Rasmussen and Doman, 1943).

Since 1936–37 the Utah Unit has experimented with supplemental concentrates on the feed-ground. Linseed meal, cottonseed, cake, cattle pellets,[2] deer ration,[3] and dried beet pulp and beet molasses,[4] were tested early in 1937. Except for the deer ration, these are commercial concentrated often used as supplements for range livestock. All were palatable to deer, but uncontrolled conditions prevented accurate determinations of relative preferences or value. Degree of use apparently depended on climatic conditions during the time they were available. On cold days all were taken completely, but in moderate weather some preference was indicated. Those based on times when not all concentrates were eaten were, in order, (1) cottonseed cake, (2) cattle pellets, (3) deer ration, (4) dried beet pulp and beet molasses, and (5) linseed meal.

Limbs of ornamental and fruit trees also were fed experimentally; the twigs and buds of most species were highly palatable, but it was impossible to supply enough to benefit the many deer present.

In 1939, from late February until early April, six tons of pea silage were fed. The deer seemingly welcomed this succulent feed after having been on alfalfa hay since November. It was eaten readily and proved an effective bait to lure deer into traps for tagging. In two subsequent years this food was not taken readily early in winter, apparently not being relished until the animals had been on dry feed for some time. Pea silage is not highly nutritious, but stomachs of a few that died on the feed-ground during the winter of 1938–

[2] Globe A-1 Cattle Pellets, Globe Mills, Ogden, Utah. Ground corn, barley, oats, wheat, mixed feed, cottonseed meal, bone meal, salt and molasses. Guaranteed analysis: Minimum crude protein, 16.0%; minimum crude fat, 4.0%; maximum crude ash, 7.0%; maximum crude fiber, 8.0%; carbohydrates, 65.0%; minimum crude nitrogen free extract, 53.0%.

[3] Unicorn Deer Ration, Chapin and Company, Hammond, Indiana. Cottonseed meal, linseed meal, dried brewers grains, gluten seed, bran, standard middlings, corn, ground barley, salt and lime. Analysis: Protein, 20%, fat, 4.5%; fiber, not over 10%; carbohydrates, 50%.

[4] Dried Beet Pulp and Beet Molasses, Utah-Idaho Sugar Co., West Jordan, Utah. Only the residue of sugar beets dried after extraction of sugar. Contents: Crude fat, 0.5%; protein, 8%; carbohydrates, 60%.

39 were full of it. There were indications that it has a laxative effect.

FEEDING EXPERIMENTS, 1940–43

The preliminary tests indicated that accurate determinations of palatability and nutritive qualities of various feeds and the effects of winter feeding could not be gained solely by feed-ground experiments. More detailed experiments, therefore, were initiated; these included the feeding of penned animals, and checking the results by offering various supplements on the feed-ground under better controlled conditions than were possible earlier.

FEEDING OF PENNED DEER, 1940–43

A four-pen corral was constructed (Fig. 2); each pen was 50 by 100 feet and equipped with feed and water troughs and facilities for trapping and weighing the animals. The walls were nine feet high, of regular net stock fence lined on the inside to a height of six feet with heavy 1½-inch mesh foxwire. The foxwire excluded other animals and prevented the deer from getting their heads and legs caught or injured in the net wire. In each enclosure a triangular handling pen was constructed by fencing off one corner; this contained the water and feed troughs and feed shelter and led into a covered chute 15 feet long. The deer were weighed periodically by trapping in the handling pen when they came in to feed. Each was then pushed into the chute,

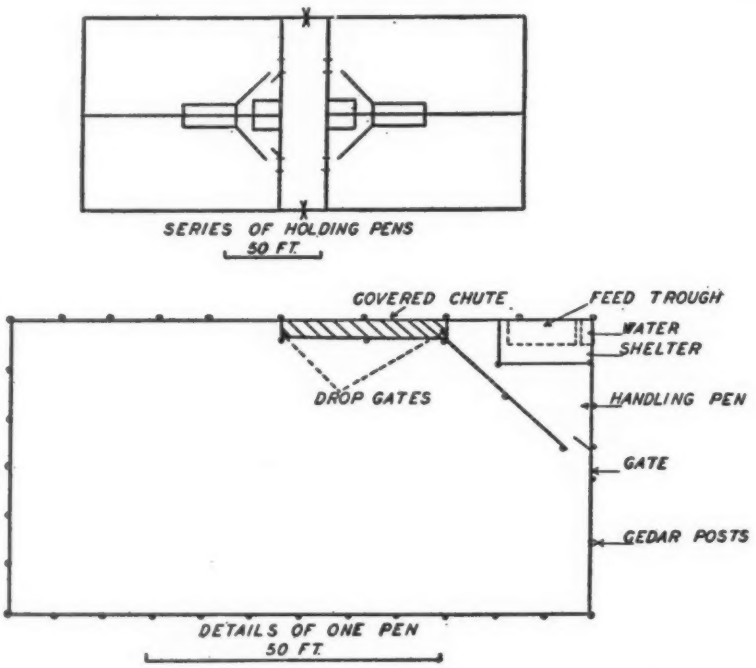


Fig. 2. Plan of deer-holding pens used in experimental feeding studies at Cache Experimental Area, North Logan, Utah.

crated, and placed on the scales.

Since 80 to 97 per cent of the winter losses from malnutrition occurred in fawns, this age group was used. Fawns became tame more readily than mature deer, and their uniform size and age made them better experimental animals.

The deer were trapped from the wild and placed in the pens early in winter and fed daily on various diets of hay, grain, and concentrates. All feeds were weighed and any material not eaten was reweighed upon removal. The animals were weighed at intervals to determine their response to the various feeds.

During the three winters from 1940 to 1943 nine diets were tested on 24 different animals. Except for one yearling in 1942–43, all were fawns, 7 to 10 months old (the yearling was a fawn fed in 1941–42 and retrapped in 1942–43). Each diet was used on two to five deer for periods of 21 to 67 days (Table 5).

Previous observations had shown definitely that timothy and native grass hay were unpalatable to deer and that alfalfa hay is preferred to the other types of hay readily available in Utah. Hence alfalfa was used in all the diets and in quantities that gave the deer access to more than they would eat. The concentrates usually were limited to a pound or less per animal per day.

All diets except No. 5 contained commonly used concentrates and were made as practical as possible so that if successful with penned deer they could be tried on the feed-ground. In No. 5 a variety of feeds was offered and special care was taken throughout the feeding period to have an excess of all in the troughs. This allowed free choice of items and provided data on relative palatability. Rolled barley made up a greater percentage of the diet than any other item, followed by alfalfa hay, apple pomace, and sheep pellets. Whole oats and dried beet pulp with molasses were not highly palatable.

Alfalfa hay of good quality was the sole item in two trials (Diets 1 and 6). Penned deer ate more hay than the average deer on the feed-ground, although ample quantities were available in both cases. From January 28 to March 21, 1941, four fawns consumed 2.54 pounds of alfalfa per hundredweight per day and lost 18.04 per cent of their January weight. Two (on Diet 6) from February 5 to March 27, 1942, consumed 3.15 pounds per hundred-weight per day and lost 5.19 per cent of their initial weight. This loss was less than sustained by deer on the feed-ground for the same period as indicated by retrapping tagged fawns.

Chopped alfalfa (Diet 2) was fed in an attempt to overcome the wastage of alfalfa stems on an open feed-ground, but proved low in palatability. In one trial three fawns consumed only 1.26 pounds per hundred-weight per day and their weight losses were so rapid (0.88% per day) that they were taken off the diet after a 21-day trial; one died after 10 days on this diet.

Use of dried beet pulp and molasses with whole and chopped alfalfa (Diets 3 and 4), gave results similar to those from alfalfa hay alone. On Diet 3 the deer were limited to 1 pound per animal per day; it was taken readily and consumed before the chopped alfalfa. When hay and pulp were mixed in approximately equal amounts the deer usually

TABLE 5.—RESULTS OF FEEDING SUPPLEMENTS TO PENNED FAWNS OF MULE DEER AT CACHE EXPERIMENTAL AREA, UTAH.
Diets 1 to 4, 1940–41; diets 5 to 8, 1941–42; diet 9, 1942–43.

Diet no.	No. of fawns fed	Materials	Per cent of diet	Total days; dates fed	Feed (air dry basis) consumed per 100 lbs. per day	Weight losses, percentage	
						For period	Per day
1	4	Alfalfa hay	100.0	52 1–28 to 3–21	2.54	*18.0*	*.36*
2	3	Alfalfa hay, chopped	100.0	21 2–28 to 3–20	1.26	*18.4*	*.88*
3	4	Alfalfa hay Dried beet pulp and molasses[a]	72.8 27.2	21 3–21 to 4–10	2.25	*6.4*	*.30*
4	2	Alfalfa hay, chopped Dried beet pulp and molasses	52.9 47.1	21 3–21 to 4–10	1.72	*17.4*	*.83*
5	4	Alfalfa hay Rolled barley Apple pomace Sheep pellets[b] Whole oats Dried beet pulp and molasses	23.8 31.1 16.8 13.3 9.4 5.6	54 2–3 to 3–28	3.69	*1.0*	*.02*
6	2	Alfalfa hay	100.0	51 2–4 to 3–27	3.15	*5.2*	*.10*
7	4	Alfalfa hay Sheep pellets	73.5 26.5	50 2–6 to 3–27	2.68	*5.4*	*.11*
8	2	Alfalfa hay Whole barley	59.9 40.1	53 2–4 to 3–28	3.57	*0.2*	*.01*
9	5[c]	Alfalfa hay Sheep pellets Whole barley		67 1–5 to 3–12 1–5 to 2–15 2–16 to 3–12		*0.6* gain	*.01* gain

[a] Residue from sugar beets with molasses, Larrowe Milling Company, Los Angeles. Guaranteed analysis: Crude protein, not less than 6.5%; crude fat, not less than 0.30%; crude fiber, not more than 18%; nitrogen free extract, not less than 50%; ash, not more than 8%.

[b] Concentrate Purina Sheep Pellets, Ralston Purina Co., St. Louis, Mo. Ingredients: Soybean oil meal, cottonseed meal, linseed meal, bean meal, corn meal, ground barley, ground wheat, ground oats, wheat middlings (grey), molasses, 3% steamed bone meal, 2% iodized salt. Guaranteed analysis: Crude protein, not less than 12%; crude fat, not less than 2%; crude fiber, not more than 9%; nitrogen free extract, not less than 50%; ash, 11%.

[c] One yearling doe.

ate all of the mixture, but if considerably more hay than pulp was included they usually left some hay after picking it over. In a pen where chopped hay was fed with the pulp, one fawn died after 15 days.

Of interest in the failure of deer to subsist on chopped alfalfa, is the work

by Cole and Mead (1943) who reported serious disorders when finely ground alfalfa was fed to domestic ruminants. These included failure or reduction in rumination, difficulty in eructation, lessened food intake, and depraved appetite. The authors attribute the disorders to a lack of coarse material believed necessary to stimulate proper functioning of the rumen.

The experiments with alfalfa showed that when fed alone it will not maintain the weight of fawn deer in winter. On two diets, however, the deer did maintain their weight. Alfalfa hay supplemented by 0.9 pounds of barley per animal per day (Diet 8), was fed to two fawns from February 4 to March 28, 1942; they consumed 3.57 pounds per hundred-weight per day, of which there was 59.9 per cent hay and 40.1 per cent barley. One animal gained 0.50 pound and one lost 0.75 pound. Of the diets tested, this one appeared to be most practical for feed-ground use.

Diet 9 proved to be a maintenance ration; from January 5 to March 12, 1943, it was fed to four fawns and a yearling doe. This diet consisted of alfalfa hay supplemented from January 5 to February 15 by about 1 pound of "Purina" sheep pellets per deer per day, and from February 16 to March 12 by the same amount of barley. The hay was not weighed, but a supply was always available. One fawn lost 2.25 pounds and the others made slight gains, the average gain for the period being 0.63 per cent of the January weights.

The pounds of total digestible nutrients consumed per hundred-weight per day were calculated for Diets 6 and 8, using digestion coefficients listed by Morrison (1939) for domestic livestock. On Diet 6 the deer consumed 1.65 pounds of total digestible nutrients per hundred-weight per day and lost 5.19 per cent of their weight during 51 days. On Diet 8, a maintenance ration, they ate 2.28 pounds of total digestible nutrient per hundred-weight per day. This was nearly the same proportion as Morrison lists for fattening lambs (2.0 to 2.3 pounds), and is more than listed as a maintenance ration for pregnant ewes (1.5 to 1.8 pounds).

FEED-GROUND DEER

During 1940–43, hay, silages, and concentrates were offered on the North Logan feed-ground, as done previously, but with more attention to the effect of various supplements on both the herd and the individual deer. Stevenson-type box traps, developed in Michigan (Bartlett, 1938), were set up and deer were caught, weighed, and ear-tagged. Retrapping and reweighing of tagged deer provided a check on their responses to various diets under feed-ground conditions. Individuals were retrapped as many as 12 times in one winter and approximately 250 different animals were trapped and weighed during the three winters from 1940 to 1943. (Previously 268 had been tagged but not weighed on this feed-ground.) Deer counts and range inspections were made to determine numbers on and near the feed-grounds and the effect of the congested population on forage plants. Winter surveys of deer losses were made each spring on the feed-grounds and on adjacent ranges.

In 1940 a small fenced area ("fawn creep") was built on the feed-ground in an attempt to give fawns access to feed

without interference by adults, but it proved impractical; no adjustment in size of entrance could be made that enabled fawns to enter readily and yet excluded adult does.

In 1938–39 various commercial preparations of salt for livestock were kept accessible on the feed-ground throughout the feeding period. The salt was variously granulated, mined rock, pressed block, and "medicated" blocks. No preference was indicated, and the amount used was less than that lost by weathering; hence salt was considered of little or no importance in supplemental winter feeding.

WINTER OF 1940–41

The winter of 1940–41 was mild, with little snowfall; deer ranged back to near the top of the mountain east of the feed-ground and the forage on both north and south exposures was accessible and utilized. Green cheat grass (*Bromus tectorum*) was available during most of the winter on the foothills and in fields at the experimental area.

An average of about 200 deer were fed from January 5 to March 12, using 12 tons of good alfalfa hay and two tons of chopped alfalfa. The former was scattered over a quarter mile strip and the chopped hay was placed in seven 14-foot troughs. The deer were offered as much as they would utilize without excessive waste. Unchopped hay obviously was preferred, as practically all the leaves and small stems would be eaten each day, whereas only limited amounts of the chopped hay were taken. About 20 per cent of the total (14 tons) remained unutilized.

In all there were 13,400 deer days use of the feed-ground; the average amount consumed per deer day was 1.67 pounds. Stomach analyses showed that the hay conprised about 60 per cent of the total diet, the remainder being native forage. The two main forage species were sagebrush (16.4% of total) and cheat grass (8.4%) (Table 1).

During January, February, and March, 34 deer were trapped, eartagged and weighed. Several were recaught and weighed at intervals; all lost weight as the winter progressed, the average of four mature deer during 61 days being 11.5 per cent of their January weights. No fawns were reweighed.

Winter losses were few; and of ten found dead four were killed by dogs, three died from accidental injuries, and the causes in three were undetermined.

WINTER OF 1941–42

The winter of 1941–42 also was open, with little snow on the winter ranges; about 900 deer wintered on the Logan-Green Canyon area, 80% being within 1¼ miles of the feed-ground. Weekly counts on the feed-ground showed the average number fed per day from December 28 to March 25 was near 400, and the maximum was 619; 28 tons of unchopped alfalfa and 12 tons of chopped alfalfa were fed during this period. Unchopped hay again was preferred and chopped hay usually was not eaten until most of the other had been consumed. The deer were estimated to have averaged 1.82 pounds per animal per day. Costs for feed and labor were $532.00, or an average of $1.33 per deer.

In stomachs of 10 deer taken on and near the feed-ground the supplemental

feed made 82.6 per cent; of the native forage, sagebrush comprised 13.3 per cent (Table 1).

The deer generally were in good condition when they appeared on the winter range and maintained their weights during the first part of the winter. Weights of trapped individuals from the feed-ground showed small losses until about February 10; thence until March 25 the fawns lost weight rapidly, and adjacent areas, although kills by both cougars and coyotes were seen on other winter ranges.

WINTER OF 1942–43

In this winter, the higher mountain areas had heavy snows, but precipitation on the lower winter ranges was largely as rain, and snow depths were less than normal on the Logan-Green Canyon deer winter range.

TABLE 6.—LOSSES IN DEER ON THE LOGAN-GREEN CANYON AREA, UTAH; WINTERS OF 1941–42 AND 1942–43.

Cause	Numbers found			Percentages
	Adults	Fawns	Totals	
Malnutrition	3	81	84	*78.5*
Dogs	1	7	8	*7.5*
Crippled during hunt	4	—	4	*3.7*
Old age	4	—	4	*3.7*
Mechanical injuries	3	3	6	*5.6*
Undetermined	1	—	1	*.9*
Totals, 1941–42	16	91	107	
Malnutrition	3	98	101	*84.9*
Dogs	—	12	12	*10.1*
Crippled during hunt	1	1	2	*1.7*
Old age	3	—	3	*2.5*
Undetermined	1	—	1	*.8*
Totals, 1942–43	8	111	119	

the average loss in four unpenned fawns for 60 days being 26.8 per cent, and 10.9 per cent in four mature does.

Many deer died during late February and in March and a number were autopsied; 107 were found and examined shortly after death in an intensive winter loss survey of the Logan-Green Canyon area. The total winter loss on the area was estimated to be about 150, or 16.7 per cent of the total population; 85 per cent of the losses were of fawns (Table 6). No losses to natural predators were noticed on the feed-ground

Deer began using unharvested alfalfa in fields at the North Logan Experimental Area about November 25 and an average of about 125 deer utilized it all by January 7, when supplemental feeding was started.

Alfalfa hay then was fed daily from January 7 to March 10, and on alternate days from March 10 to 24, using about 33 tons or 860 pounds per day for the entire feeding period. Twenty tons was exceptionally fine stemmed, first cutting alfalfa, of which the deer wasted only about 5 per cent. The other

13 tons were coarser (grown at the Experimental Area), of which about 75 per cent was eaten, leaving the stalks and larger stems. From January 16 to February 15 the supplements were 0.25 pounds of sheep pellets per deer per day (total, 2 tons), and from February 16 to March 12, 0.40 pound of barley (2 tons); both were taken eagerly. During this entire period about 400 deer, or half of those on the North Logan-Green Canyon area were fed daily, a higher percentage than fed in any previous year on the area. Apparently there was a significant increase in the dependence of the deer on supplements because the snow on nearby areas was less than normal and the west and south facing slopes were bare of snow for much of the winter. Total costs were $804.00, or $1.98 per animal; the increase over 1942 resulted from higher prices for feed and wages and the larger percentage of supplements in the winter diet.

Analyses of 10 stomachs showed that supplements comprised 85 per cent of the total, the highest of artificial feed found in any of the three years in which similar samples were taken (Table 1).

In February, 1942, a small amount of white sweet clover hay was fed one night; this was coarse stemmed, but appeared to be highly palatable. In 1943 about 200 lbs. was fed each night from March 1 to 10. At first nearly all of it was eaten, but thereafter it did not seem to be as palatable as alfalfa.

Reweights over a 45-day period during the feeding were obtained for eight fawns and six mature deer on the feed-ground; the average loss was 12.9 per cent for fawns or 0.29 per day, and 8.7 per cent for mature deer or 0.19 per day. Projected to 77 days (the length of the 1943 feeding period) this would amount to an average loss of 22.1 per cent for fawns and 14.9 per cent for adults.

From March 24 to 27, an intensive search was made for dead animals on about two-thirds of the area from which deer had been coming to the North Logan feed-ground; 119 (93%) fawns) were found (Table 6) and an estimated 175 deaths occurred on the area. A census showed about 800 deer wintering on the area, of which 320 (40%) were fawns. Therefore, the winter loss was approximately 22 per cent of the total population and 50 per cent of the fawns.

Such a large loss appears paradoxical among deer visiting the feed-grounds, where materials were fed that proved a maintenance diet for penned animals. From field observations it appeared that either the deer (1) failed to eat sufficient supplements to prevent undue loss of weight and made unsuccessful attempts to obtain native forage from the range, or (2) experienced a physiological upset in attempting to change, while emaciated, from a diet of browse and dry supplements to one including early green succulents, attractive enough to make them desert the feed-ground but lacking suitable nutrients or quantity to permit them to survive.

DISCUSSION

OTHER BIG GAME FEED-GROUNDS

Observations in northern and central Utah and in other intermountain states showed close correlation between the supply of native forage and the winter losses among deer. With an abundance

of even the less valuable browse plants such as sagebrush (*Artemisia* spp.), juniper (*Juniperus* spp.), and scrub oak (*Quercus gambelii*) there have been no marked losses during usual winters. The more dependent the deer become upon supplements, the greater the winter losses. Large losses were practically all due to malnutrition, and were greatest among the fawns; disease and parasites appeared unimportant as direct causes of death. In no place did artificial winter feeding successfully replace browse where there were too many deer for the available winter forage.

On several winter ranges having ample native forage and where no artificial feeding had been done, field surveys during winters in which heavy local losses occurred showed no losses from malnutrition. Such deer appeared to be much thriftier in the spring than those surviving by supplemental winter feeding.

No elk used the North Logan Feedgrounds, but occasional individuals or groups were present on the adjacent winter range during several winters. Each year however, several hundred elk, were fed alone or with deer on feed-grounds along the western border of the Cache National Forest, both north and south of Logan (Fig. 1). The elk reacted somewhat differently than did the mule deer to winter feeding of hay; they ate both alfalfa stems and grass hay (unpalatable to deer) but definitely preferred choice alfalfa hay. They also appeared to make better use of supplementary feeds and from all appearances were more satisfied with this type of diet.

Certain of the same faults and difficulties in the program for deer were evident with elk. Nearby ranges were over browsed and severely damaged by the concentration of elk near the feedgrounds, supplements were not as satisfactory as native forage in maintaining them in good condition, deaths were greatest among the young, and rate of losses increased as the period of supplemental feeding was prolonged. Our observations on winter feeding of elk in other intermountain states indicate the same adverse results as seen in Utah.

WINTER FEEDING OF DEER IN OTHER AREAS

Local problems of over-abundance and concentrations by big game, particularly deer, have confronted many states during recent years. These usually occur on winter areas and individuals and organizations in various localities have undertaken winter feeding as a humane and necessary program to maintain large game populations. A review of available reports on winter feeding of deer, both mule and white-tail, does not indicate methods or diets that have proved successful in preventing winter losses.

In New York State, experiments on feeding white-tail deer were made during the winter of 1932–33 (Maynard, *et al.*, 1935). Alfalfa proved impractical and compared unfavorably with a deer cake formulated as a result of the experimental feeding; recently, however, it has been concluded that a solution to the deer concentration problem lies in reduction of numbers and not in artificial feeding.

Gerstell (1942) reviewed the problem of winter feeding in practical wildlife management and emphasized how dif-

ficult it would be to provide and distribute the large amount of feed necessary to benefit a deer herd. One of his illustrations (p. 111) shows a dead white-tail fawn at a winter feeding shelter in Pennsylvania where it had "gorged itself, only to perish in agony within a few hours."

In a report on "Michigan's Deer Problem," Bartlett (1938) says "Winter feeding has not as yet been successful nor may it ever prove to be a feasible method of holding up declining deer populations. The clubs have fed tons of hay but scarcely any beneficial results have been noticed and starvation losses continue to be huge."

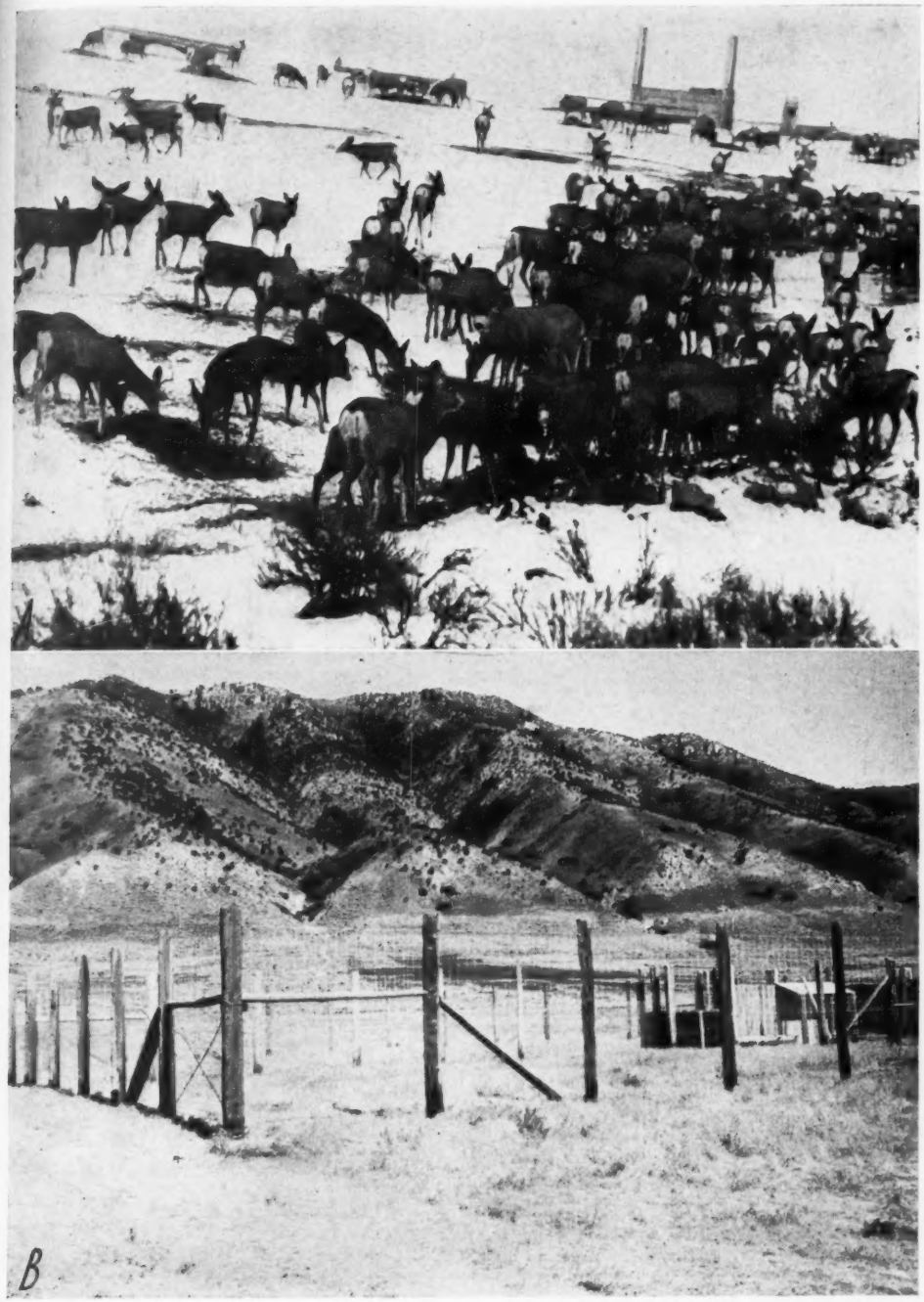
Alfalfa hay has been used in experimental feeding of deer in a number of cases. Davenport (1939) concluded that alfalfa alone for penned white-tailed deer in Michigan was "satisfactory for maintaining deer in good health and strength for a 90-day [winter] period." These deer lost 16.1 per cent in weight during the trial. During experimental tests with both white-tailed and mule deer in Arizona, Nichol (1938) found that "deer would under no circumstance eat the stems [of alfalfa], but alfalfa leaves fed with whole shelled corn, rolled barley, and whole oats in ratio of 3–1–1–1 proved to be a maintenance diet when 2.2 lbs. per hundred-weight was fed each day."

A report on winter feeding of mule deer in Colorado during 1939 and 1940 in which alfalfa and prepared stock concentrates were used on feed-grounds says "the feeding program—is unsound at present. The clear indication is that the whole question of wintering deer in this region rests on having sufficient natural feeds—available to carry the herd in normal weather—the idea that we can supply deer herds a sustaining ration by offering domestic stock feeds is unsound, uneconomic, and destructive" (Carhart 1943). A visit to the Colorado deer and elk feed-grounds in the Sapinero district and a review of their winter feeding operations by the junior author in December 1939 showed very similar conditions, problems, and results as found on the Utah areas here described. Alfalfa did not prove a satisfactory substitute for native browse and, when fed alone, whole or chopped, or with other supplements, did not prevent serious losses from malnutrition. The deer refused the coarser alfalfa stems, and winter losses, particularly of young, were common on all feed-grounds where there was a shortage of native forage.

CLIMATIC FACTORS IN WINTER LOSSES

Excessive winter deaths among big game are often attributed to a "hard" or "severe" winter—an "act of God"—a phenomenon man cannot modify or correct. Our detailed studies during eight winters on ranges in northern Utah and visits to big game ranges throughout Utah and in five bordering states clearly indicate over-emphasis and exaggeration in ascribing heavy winter losses to "hard winters." Ready acceptance of this explanation often is responsible for failure to attack the problems of overpopulation realistically and attempt solutions and is also the cause for serious and unjustified waste of funds and the wildlife resource itself.

On the basis of our studies, excessive winter losses in mule deer by severe winters resulted only in so far as deep



A. Mule deer congregated on North Logan winter feeding ground. *B*. Experimental feeding pens and adjacent winter range area between Green and Logan canyons; summer view.

A. Congregation of mule deer on winter feeding ground at North Logan. *B*. Foothill area between Logan and Green canyons in winter (compare Pl. 17 *B*). *C*. Overbrowsed ("highlined") juniper (*Juniperus utahensis*) on winter range between Logan and Green canyons. *D*. Mule deer on foothills, adjacent to feed-grounds in northern Utah.

A. Congregation of mule deer on winter feeding ground at North Logan. *B*. Foothill area between Logan and Green canyons in winter (compare Pl. 17 *B*). *C*. Overbrowsed ("highlined") juniper (*Juniperus utahensis*) on winter range between Logan and Green canyons. *D*. Mule deer on foothills, adjacent to feed-grounds in northern Utah.

snow limited the amount of forage accessible. Lack of direct climatic influence was clear because heavy losses: (1) often occurred on very local and spotted areas where deer were overly abundant and did not take place uniformly over contiguous ranges; (2) were observed four times during eight winters in the Logan Canyon herd, a period without a comparable number of severe or unusual winters having deep snows, subnormal temperatures or both; (3) are known and recorded only for recent years in northern Utah.

A generalized and not unusual example will show the relation of excessive winter losses to climatic and forage conditions on the foothill type of winter range that mule deer ordinarily occupy in the intermountain region. A unit of good foothill browse range of 2,000 acres, in an average growing season, can produce forage for 2,000 deer-months of use. This will be utilized fully by 500 deer remaining on the area from December 1 until April 1, the usual period of winter concentration with average snowfall conditions; it will be under-utilized when snowfall permits the deer to remain less than four months. In a "hard" winter, deep snow will force the 500 deer onto the range earlier and keep them there later or after the range has been fully utilized; if this usage is severe enough, there will be losses from malnutrition and related causes. Ordinarily, however, any one deer herd does not have a stable population—the 500 one year can well become 600 the following year, or 650 to 720 in two years (at the same time providing 25 to 50 bucks a year to hunters); 700 on the 2,000 acre unit during four months of an "average" winter will need 2,800 deer-months of forage or 40 per cent more than the normal of 2,000 deer-months of forage. This would be serious enough, but the 600 deer of the previous winter would be in excess of the carrying capacity, would over use the range, and would injure the plants until the range would produce less than 2,000 deer-months of forage. The forage requirement would be 40 per cent more than that produced. The range itself will be injured further, the entire herd subjected to starvation diets, losses from malnutrition (especially among the young) will be heavy, and the weak and emaciated animals will experience increased losses from predation and other causes.

Records of the climate and winter snow depth for Logan and vicinity for the past 26 years (the period with records on deer numbers) were reviewed to determine their possible relation to winter deer losses. The data consisted of regular U. S. Weather Bureau records for temperature, precipitation, and snowfall at Logan, and monthly winter snow depth records from several stations in Logan Canyon made by the School of Engineering, Utah State Agricultural College. The five most severe winters, as evidenced by excessive snow depths on both February 1 and April 1 of the same year, were, in order, 1935–36, 1922–23, 1931–32, 1926–27, 1916–17.

The first large known deer losses occurred in 1935–36, a year of average winter temperatures but exceptionally heavy late snow (Feb. 1, at 7,000 feet elevation, 41.7 inches; April 1, 60.6 inches). The winter of 1936–37 was one of the coldest on record, but with a snowfall near average; no major losses

occurred that year. In 1937–38 there were mild temperatures and little precipitation during midwinter (snow at 7,000 feet: February 1, 23.1 inches; April 1, 42.2 inches. At Logan the snow fall was: December, 12 inches; January, 1 inch; February, 14 inches; March, 14.5 inches). In no month was the mean monthly temperature below freezing.

The heaviest recorded losses were in 1938–39. Snowfall was near average in the mountains, but heavier than average on the lower foothills. At Logan the records were: December, 12 inches; January, 27 inches; February, 13 inches; March, 11 inches. The temperatures were extremely low, the average minimum for February 1939 being about 5° F. A heavy snowfall on March 4 was followed by death of many deer from March 5 to 20, and losses continued into April.

The winters of 1939–40 and 1940–41 were mild, snow depths were below the average, and the deer foraged over a wide area including much not accessible to them in average winters; the losses were low. Snowfall in 1941–42 was average or less; but increased numbers of deer congregated on the lower depleted ranges for longer periods and serious losses resulted. In 1942–43 snowfall was above the average at high elevations, deer were forced to the lowermost and badly depleted ranges, and again there were heavy losses.

CAUSES OF LOSSES

When deer were first reported as dying in large numbers on Utah winter ranges, many persons believed that disease and parasites were responsible. This was emphasized by the occurrence, in practically all dead deer, of many larvae of the nose bot fly (*Cephenomyia pratti*) and of the winter tick (*Dermacentor albipictus*); the latter matured and became conspicuous at the time of the losses in early spring. Lice (*Tricholiperus parallelus* and *T. virginianus*) lung worms (*Dictyocaulus viviparus*), and bladder worms (*Cysticercus tenuicollis*) were present, and pneumonia was often the immediate cause of death. Examination of healthy deer from good winter ranges, however, showed heavy infestations by these several common parasites without producing heavy death losses. This was similar to the experience in Michigan where Bartlett (1938) reported "When deer first were reported dying in yards in 1926 and for some time afterward, it was thought that the loss might be caused by a disease or parasite."

In March 1936, Drs. O. G. Larsen and D. E. Madsen of the Veterinary Department, Utah State Agricultural College, and the junior author made detailed post mortem examinations on mule deer from areas in northern Utah where losses were occurring. These included animals that had just died and also both weak and healthy appearing individuals shot for examination. All had parasites, but there was no indication of either the parasites or disease being the primary reason for death or weakness in certain deer. The emaciated deer, weak or dead, evidenced starvation by the absence of fat in the omentum mesentery, around the kidneys, and in the coronary groove of the heart. Also the heart was flabby and showed gelatinous infiltration. General examinations then were made of many deer found dead in the field. Most of them were extremely emaciated, all fat

from the body cavity had been used up, and there were regular signs of breakdown of the tissues and muscles—all evidences of starvation. The stomachs usually were filled or more than half filled with food; death evidently was not due to lack of food but rather to improper diet or malnutrition.

During the heavy losses in March 1939, Drs. E. R. Quortrup and A. L. Holt of the U. S. Fish and Wildlife Disease Research Station at Brigham City, Utah, examined 11 fawns (6 males, 5 females) at the North Logan feed-grounds. The stomachs were filled with food, yet all were uniformily emaciated; all had nose bots, winter ticks, and lice; and in several there were also lung worms, tapeworm cysts, and whip worms. Two males showed no pathological lesions; two females and three males had signs of pulmonary edema or pneumonia from parasitic infestations. Two females and one male had perforated gastric ulcers resulting in peritonitis, possibly the result of ingesting coarse stalks of browse that injured the stomach lining. The investigators concluded that the emaciated condition in all indicated malnutrition as the primary factor, but the actual cause of death was pneumonia in some and peritonitis in others.

From 80 to 93 per cent of the deaths during the four winters of excessive losses in the present study were attributed to malnutrition, and up to 97 per cent of such losses were in fawns of the previous summer. Most of the losses occurred during March, after the weather had moderated. Many deer died after leaving the feed-ground and while trying to subsist on the new green growth of forbs and grasses. The second highest cause of losses was by domestic dogs at the Logan-Green Canyon area, but did not occur generally on winter deer range; 4 to 12 were killed each year by dogs and nearly as many dogs were shot in attempting to prevent such loss. This area of deer congestion is close to cities and farms and losses occurred throughout the winter. Other lesser factors of loss were wounded animals, mechanical injuries, old age, and undetermined. No kills by wild predators were seen on the Logan-Green Canyon area; on nearby winter ranges cougar kills appeared consistently through the winter, but predation by coyotes was heaviest during early spring when the deer were in poorest physical shape. No losses from specific or infectious diseases were observed on the feed-grounds or congested winter ranges. Murie (1930) reported the loss of elk calves in Wyoming on a winter feed-ground from disease influenced by winter feeding.

The unnatural crowding of several hundred deer on the feed-grounds appeared to provide conditions favoring the spread of parasites, but none of the data showed clearly an increase in parasitism from the congestion.

SUMMARY AND CONCLUSIONS

1. A review of records of supplemental winter feeding of deer in various states shows no method or diet that has proven entirely successful, although supplemental feeding sometimes has been publicized as a solution to prevent winter losses.

2. In northern Utah, large losses up to nearly 20 per cent of the population and primarily of fawns, 7 to 10 months of age, occurred even during average

winters despite careful attempts to prevent such losses by feeding supplements.

3. *Heavy winter losses are not normal in mule deer,* as evidenced by the few losses on areas *where sufficient native forage is available to provide feed.*

4. Various supplements have been given to mule deer on the North Logan feed-ground, both singly and in combination. These include chopped and unchopped alfalfa, native grass hay, sweet clover hay, pea silage, barley (whole and rolled), oats, "Purina" sheep pellets, cattle pellets, cottonseed cake, linseed meal, dry beet pulp and molasses, special prepared deer ration, and apple pomace. None of these appears to replace native forages successfully.

5. Under usual feed-ground conditions, alfalfa seems to be as satisfactory for an emergency food as any available supplement on ranges where there is a fairly good supply of even the less palatable forage species, such as sagebrush and juniper. The feeding of alfalfa, however, will not prevent losses when the range is depleted so that deer must depend heavily on the alfalfa for two months or longer.

6. The time limit for successful supplemental feeding is about two months, as determined by repeated tests and study of weight losses in deer on a feed-ground. Weight losses in retrapped animals on the feed-ground is more serious in the younger animals, the average in four fawns during a 60-day period, in 1941–42 was 26.7 per cent. In 1942–43, 8 fawns lost 17.2 per cent of their January weights. For adults, the losses over a similar period were not as great, 10.9 per cent in 1941–42 and 11.6 per cent in 1942–43 of the January weights. January weights were definitely less than the peak weights in autumn. Observations over several years make it doubtful that mule deer ordinarily will survive a winter loss greater than 30 per cent of their autumn weights.

7. Pen feeding experiments with fawns showed that a diet solely of alfalfa hay was insufficient to maintain their weight, even for short periods.

8. Diets of 60 per cent alfalfa and 40 per cent barley or "Purina" pellets prevented weight losses in penned deer over a 67-day feeding period. Such a diet would cost well over $1.50 per animal for a 60-day period. This appears prohibitive in terms of present returns from hunting licenses and the necessity of maintaining several animals to provide for a sustained annual removal of one legal deer by hunting.

9. The more that deer became dependent on the supplemental feeds and less on native forage, the greater were the winter losses. So long as some native forage was available, the deer continued to browse upon it even with an abundant offering of supplements.

10. The entire policy of supplemental winter feeding for deer is considered impractical as a welfare program, and also from the standpoints of finance and range management. Artificial feeding serves to concentrate deer in small areas year after year where the animals do serious and possibly irreparable damage to native forage species; in turn, this further reduces the carrying capacity of the range and makes the deer increasingly dependent on supplements.

11. The large death losses among deer during late winter and early spring on and adjacent to the feed-grounds, proved to result almost entirely from malnutrition—lack of sufficient quantity or suitable quality of available food or a combination of these. Numerous autopsies throughout the study period showed no disease as a primary or important cause of losses; the deaths were of emaciated animals that showed definite evidence of malnutrition in the post-mortem examinations. As a rule, however, the deer were infested with various external and internal parasites, and pneumonia (non-infectious) frequently was found to be the immediate cause of death.

12. The common assumption that increased and abnormal winter losses among mule deer result directly from "severe" or "hard" winters proved to be only partly true in northern Utah. On the basis of observations during eight winters, climatic conditions were responsible for major losses only in so far as deep snows forced the animals to concentrate on limited winter ranges having insufficient forage; excessive losses occurred in "normal" or "mild" winters if the deer were too numerous for the available forage on the ranges they occupied.

RECOMMENDATIONS

1. Experience with supplemental winter feeding of mule deer indicates that at best it is only partly successful and expansion of such a program is of doubtful value. It appears desirable to regulate the deer population so that supplemental winter feeding as a regular program can be discontinued.

2. Removals during the regular hunting season should be heavy enough to reduce the population on all ranges where supplemental feeding has been necessary. Where this is impossible, deer on concentration areas near feed-grounds should be reduced by post-season hunting at a time when the meat can be utilized.

3. Until the deer populations now on certain congested winter range areas near present feed-grounds are reduced, some feeding will probably be needed in attempts to keep the animals from invading and damaging private property. Such feeding should be delayed as long as possible in the early winter, however, to discourage them from congregating on these small areas.

4. Under usual conditions on a feed-ground, fine-stemmed leafy alfalfa appears to be the most practical and economical supplement if feeding is necessary for two months or less. For any longer period, feeding is questionable, economically, and ordinarily results in large winter losses. Under feed-ground conditions, these losses are not prevented by offering expensive concentrates with the hay.

5. To prevent the development of additional concentration areas, careful surveys of forage utilization should be made on all deer winter ranges after each winter season. Management of the herds and planned removals during the subsequent hunt should be based more on the conditions of the forage than on the numbers of deer counted or estimated during the winter census.

6. Because of the undesirable conditions and the losses that develop on and near feed-grounds, the solution should

lie in attempts to adjust deer populations to the carrying capacities of their winter ranges rather than in further search toward methods and diets for supplemental winter feeding.

7. A sound program of lasting benefit to improve winter feed conditions and provide additional winter food for mule deer must depend on additional permanent sources of natural forage.

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BRIEFER ARTICLES

ESTIMATING ACORN CROPS FOR WILD LIFE IN THE SOUTHERN APPALACHIANS

Acorns are important in the food of deer, squirrels and turkeys during the autumn and early winter, and the results of a recent study (Downs, A. A. and W. E. McQuilkin, Seed production of southern Applachian oaks. Journ. Forestry, in press) will be useful to game managers for computing the part of acorns in total carrying capacity of an area. Quantitative data on seed production and on seed destruction by insects, birds, and animals were sought for five of the more valuable oaks in the southern Appalachians. For 105 trees in the Toccoa Experimental Forest, Union County, Georgia, and for 105 trees in the Bent Creek Experimental Forest, Buncombe County, North Carolina, acorn production was sampled by seed traps, and animal depredation by open quadrats under these trees. The traps and quadrats were examined at 1- to 2-week intervals from the time seed first began to drop until February or March. Acorns in the traps were classified as: (1) well developed and apparently sound, (2) well developed but damaged by birds or squirrels, (3) well developed but showing insect emergence holes, and (4) imperfectly developed, deformed, or aborted. Those in the first group were cut open to determine the number which actually were sound. Acorns in the open quadrats were counted at each examination, then rescattered in the quadrats. Over a 7-year period, 53 per cent of all acorns collected were imperfectly developed; of those well developed when dropped from the trees, 24 per cent showed bird or squirrel damage, 30 per cent were insect-damaged, and 46 per cent were sound. While on the ground, a large proportion of these sound acorns subsequently are destroyed by insects or eaten by animals. With scant animal populations, most of the sound acorns are consumed when the crops are light but a fair surplus is left from good crops. With high deer populations (as on the Bent Creek Experimental Forest) practically the entire crop is consumed except in years of heavy production.

If the numbers of oaks per acre by d.b.h. (diameter breast high) classes are known for a given area, data on the number of acorns produced by trees of different sizes and species (Table 1) can be applied to obtain an estimate of the number of acorns produced per acre per year. The weights, in pounds,

TABLE 1.—AVERAGE NUMBERS OF WELL DEVELOPED ACORNS PRODUCED ANNUALLY PER TREE SPECIES AND TREE DIAMETER (7 YEARS, 210 TREES).

Diameter, inches	Chestnut oak	White oak	Eastern red oak	Black oak	Scarlet oak
10	60	110	40	260	480
12	210	240	200	405	750
14	350	460	510	550	1,070
16	460	750	900	695	1,530
18	560	1,120	1,310	840	2,320
20	630	1,560	1,560	985	3,090
22	680	1,890	1,540	1,130	3,370
24	710	2,080	1,400	1,275	3,490
26	730	2,180	1,240	1,420	3,520
28	740	2,160	1,080	1,565	3,520
30	750	2,080	900	1,710	
32	750	1,940	720	1,855	
34	760	1,760	540	2,000	
36	760	1,520	360	2,145	

from samples taken over several years, were as follows:

Species	*Weight per 100 acorns, pounds*	*Number of acorns per pound*
Black oak	0.41	241
Scarlet oak	0.52	194
White oak	0.60	166
Eastern red oak	1.11	90
Chestnut oak	1.44	69

on a 2,100-acre tract in the Bent Creek Experimental Forest of western North Carolina. This tract includes the major oak associations found in the southern Appalachians. An average acre produces about 123 pounds per year (Table 2), and the entire unit about 258,000 pounds or 129 tons of mast for wildlife. The oak type, covering 1,500 acres on this unit, averages about 5,400 board feet per acre, gross volume, in oak trees 10 inches d.b.h. or larger, with an average of 27 oaks per acre of this size and larger. This is probably somewhat better than the average of southern Appalachian oak stands which usually have been cut over much more heavily than the study area. In this oak type about 147 pounds of acorns per acre are produced annually. In years of crop failure, very few well developed acorns are produced, while in years of heavy production, 2 to 3 times this amount may result.—ALBERT A. DOWNS, *Applachian Forest Experiment Station, U.S. Forest Service, Asheville, N. C.*

TABLE 2.—COMPUTED AVERAGE ACORN CROP PER ACRE FOR A 2,100-ACRE SAMPLE; BENT CREEK EXPERIMENTAL FOREST, NORTH CAROLINA.

Species of oak	All types		Oak type	
	Number of acorns	Weight pounds	Number of acorns	Weight pounds
Black	1,980	8.1	2,410	9.9
Scarlet	4,260	22.1	4,060	21.1
White	2,620	15.7	3,120	18.7
Eastern red	1,600	17.7	1,990	22.1
Chestnut	4,110	59.2	5,190	74.7
Totals	14,570	122.8	16,770	146.5

These are for fresh, well developed acorns with no apparent defects, about 5 days after dropping from the trees. Acorns infested with insects, but from which the larvae had not emerged, were included in the weighings. Acorns may change in weight after dropping from the tree; they may lose by respiration, desiccation, or insect depredation and may gain by water absorption, especially those of chestnut and white oaks, which germinate in the autumn.

The number of acorns and the weight of the crop to be expected were computed for the oak type alone and for all types combined

AIRPLANE RECONNAISSANCE OF SEA LIONS IN WASHINGTON

On March 21, 1944, by courtesy of the United States Coast Guard, we observed all coastal waters for about 100 miles from the southern end of Vancouver Island, B.C., to Point Grenville, Washington, from an airplane. There are no rocks suitable for sea lions south of Point Grenville and in two hours we saw virtually all of the range of the Steller sea lion (*Eumetopias jubata*) in the State of Washington. Most of the flight was at an elevation of 800 feet, but near rocks where sea lions or their conspicuous white droppings were visible, our pilot obligingly dropped to 200 feet for closer examination.

We saw about 75 sea lions covering nearly all available space on a small rock off Bonilla

Point, Vancouver Island, and the pilot had seen a similar group there about March 1. These individuals undoubtedly forage in Washington waters on occasion. On a low, unnamed rock 1½ miles west of the mouth of the Ozette River, there were about 50, and on Jagged Island, which has the reputation of supporting the largest herd on the Washington coast, about 150 sea lions were present, in two groups. A pair of islets south of Alexander Island had conspicuous white excrement but no sea lions. These rocks probably are identical with Perkins Reef of U. S. C. & G. S. Chart No. 6102.

Between 3 and 4 miles south-by-west of the mouth of Raft River lies a group of rocky islets. On the westernmost (apparently Split Rock) at 11:40 a.m., there were 5 sea lions, and on the southernmost rock (unnamed)100. The terminology of these rocks is confusing. The entire group is referred to as the "Sea Lion Rocks" by the Quinault Indians and is so named on modern maps of the National Park Service, Forest Service, and State Department of Highways. Chart No. 6002 shows six and names two, Willoughby Rock and Split Rock. This chart shows a "Sealion Rock" 3 miles to the northwest which we visited but saw neither sea lions nor white excrement which would indicate their recent presence.

All of the sea lions seen were adults or subadults; there were no young of the season. In most cases their pelage was dry and light brown or golden. None was observed on Destruction Island, Tatoosh Island, in the Strait of Juan de Fuca as far east as Port Angeles, or elsewhere along our course. Considering those scattered through the San Juan Islands and in Puget Sound and feeding at sea at the time of our reconnaissance, we would estimate that about 500 sea lions occur in the State of Washington. The population may vary with the season because of the migration to and from British Columbia and Oregon but no tagging experiments to settle this point have been made.—VICTOR B. SCHEFFER, *U. S. Fish and Wildlife Service, Seattle, Washington*, and PRESTON P. MACY, *National Park Service, Port Angeles, Washington.*

NEWS NOTES

Notices for dues and subscriptions to The Journal will be mailed by the Treasurer during November. Prompt payment will ensure mailing of copies of The Journal on time and also will reduce the labors of the Treasurer and Secretary. Payments from without the United States should be made on the basis of United States currency.

Members and associates serving with the armed forces of the United States should advise the Secretary of their permanent mail addresses and as to whether their copies of The Journal should be sent to the permanent address or service address. Those now in services should keep the Secretary informed as to their rank and organization. The membership list printed in this issue contains such information as was available up to the time of printing.

The minutes of the 1944 Annual Meeting (pp. 253–255) unfortunately omitted mention of the Report of the Committee on Professional Standards. The report was mimeographed and copies were distributed at the meeting by Chairman G. O. Hendrickson.

The Missouri Conservation Commission is publishing "The Prairie Chicken in Missouri," by Charles W. Schwartz. The book, of 176 pages, 9 by 12 inches, has a full-color frontispiece and 85 photographic illustrations, each with a paragraph of explanation. The life cycle of this notable species is depicted throughout: the courting assembly and peculiar postures of cocks on the booming grounds, the arrival of females, nesting, laying, and incubation, growth of the young, autumn booming and territorial fighting, roosting, daytime activities in winter, prairie chicken habitats in Missouri, and the effect of various land uses and other human activities on the species.

The book sells for $5.00 but 50 copies will be available from the Commission (Jefferson City, Mo.) to members of The Wildlife Society at the prepublication price ($3.50) until November 15, 1944.

REVIEWS

The Armadillo: its relation to agriculture and game. E. R. Kalmbach. Austin, Texas, Texas Game, Fish and Oyster Commission. iv+61 pp., colored frontispiece, 4 pls., 4 figs. 1943.

Although initially undertaken to ascertain the economic importance of the armadillo to man, this account is of much wider scope, and proves that quality may appear in modest garb. The booklet is prefaced by an excellent colored plate by the author, describes and documents the extension of geographic range in recent years over more than half of Texas and much of Louisiana, points out that the species concerned (*Dasypus novemcinctus*) ranges from Argentina to Texas, and states "Despite the fact that armadillos undergo a period of inactivity if not actual hibernation during cold weather, severe winters and inclement weather in fall and spring have killed many and prevented further advance of the species. Captive armadillos in the writer's possession have perished when the temperature of the room in which they were kept was reduced to 40 or 50 degrees Fahrenheit for a night or two." The author thinks the species may extend its range eastward to the Atlantic Coast and the reviewer may add that this prediction seems to be in a fair way to be realized soon; H. B. Sherman (Florida Entomologist, 36 (4): 54, December, 1943), reports the armadillo as already common in parts of Florida.

"The smooth, hard covering permits the armadillo to escape readily through the tangles of thorny growth so frequent in its native environment that effectively check the progress of many predators." Without an insulating coat of fur, however, the armadillo is at a disadvantage in resisting low temperatures, and the heavy shell, unlike buoyant fur, is a handicap in swimming. The animal sometimes overcomes this handicap by walking submerged on the bottom of a stream or pond if going only a few feet; when the distance is longer, the armadillo ingests air; this distends the stomach and intestinal tract, decreases its specific gravity from 1.06 to .92, and allows the animal to swim with greater ease.

Even more remarkable, although previously well-known, is the almost invariable production of four young in a litter—identical quadruplets since they are derived from a single egg. After a variable period of delayed implantation, the fertilized egg undergoes embryonic growth for about 120 days.

A nervous response is that of jumping upward when alarmed. This is fatal to many individuals which would otherwise be unharmed by passing automobiles. The armadillo relies on this nervous response and on subsequently running to a burrow to escape enemies. Contrary to popular belief, it seldom if ever rolls itself into a ball when alarmed, as do some related species of South America.

In Texas the armadillo is crepuscular and nocturnal, living in burrows in the ground. It makes many burrows, some of which are used by other animals such as cottontails, skunks, opossums, and burrowing owls. The males weigh 13 to 17 pounds, and females about four pounds less. The flesh is light-colored and resembles pork in flavor. In years of crop failure in some areas it is eaten extensively by man, "poor man's hog" being an appellation commonly applied to the animal. More than 2,000 No. 3 cans of armadillo flesh were prepared in a single season by clubs of farm-girls working under one leader.

The charge that armadillos eat many eggs, including those of poultry, is not sustained, although it sometimes eats eggs small enough to be taken entire into its mouth. "More than ninety-three per cent (by volume) of the food was animal in origin and more than ninety-two per cent was comprised of insects or other invertebrates." The author credits one stomach examined in the laboratory of the Fish and Wildlife Service with holding the record number of specifically different items—at least 87 species comprising 3,100 individuals. It is concluded that the character and volume of the armadillo's insect food " . . . has an influence for good. Its misdeeds, including attacks on ground nesting birds,

and on certain crops (either through its energetic search for insects or through direct feeding) detracts somewhat from its generally commendable habits."

The reviewer wishes to point out that the armadillo is only one of several mammals of the Sonoran Provice (and of the Tropics) thought to be extending their geographic ranges northward at the present time. The cotton rat (*Sigmodon*) reported by Rinker (Journ. Mammalogy, 23: 439, 1942) from Douglas County, Kansas, is another. In the present interglacial stage, evidence of this northward extension of range which Kalmbach has recorded for the armadillo can well be watched for alertly in other organisms by all naturalists in areas along the upper margin of the Sonoran Province, so that we may have a more accurate record of the rate of shift in geographic ranges. Probably, in response to warmer and colder cycles of years, an extension of the range of a species may behave much as a rising tide on a sloping sandy beach where inspection at any one moment is about as likely to reveal a receding wave as one that is rising. The 60-year old record of an armadillo taken in Denton County, northern Texas (Forest and Stream, Nov. 13, 1884, p. 304), may have been the crest of an earlier wave now surpassed by that of recent years which has carried the armadillo northward into Oklahoma, and according to oral report (Claude W. Hibbard) even into southern Kansas.

Because the materials included in the paper are so well chosen, it can be recommended as a pattern for accounts of other mammals; all members of the Wildlife Society who read it will wish that a similar account was on published record for a representative species of each genus of North American mammal.—E. RAYMOND HALL, *University of Kansas, Lawrence, Kansas.*

The Canvasback on a Prairie Marsh. H. Albert Hochbaum. Washington, D. C., American Wildlife Institute. xii+201 pp., frontisp. (colored), 18 pls., many figs. 1944. $3.00.

The American Wildlife Institute was organized to stimulate and finance research on North American wildlife at a time when such investigations were sorely needed on many species that had been far reduced. Already the Institute has added importantly to the literature of management by publishing the transactions of the eight annual continent-wide conferences on wildlife besides Cartwright's useful volume on waterfowl. It now is undertaking the production of separate books, to disseminate the results of special studies, of which Hochbaum's "Canvasback" sets a high initial standard.

Delta Marsh, at the south end of Manitoba Lake near Winnipeg, was the site of intensive investigations on waterfowl by the author and his associates from 1938 to 1942, with Aldo Leopold, Miles D. Pirnie, and William Rowan as an advisory board on the project. The canvasback served as the "base-datum" for a study of the duck summer—from spring arrival throughout the nesting and hunting seasons and until autumn departure. Other species discussed comparatively are the mallard, gadwall, blue-winged teal, shoveller, baldpate, pintail, redhead, lesser scaup, and ruddy duck.

The chapter topics are: the Delta Marsh, spring flight, nesting season of the canvasback, nesting of other species, the brood season, the postbreeding season, autumn and the shooting season, and a discussion for management. Each chapter contains adequate but not tedious detail to support the main discussion and there is clear distinction between established facts, partial evidence, and matters still unknown.

Sharp observations and critical interpretations abound. "All females are not in the same stage of the reproductive cycle at the same time." "Sexually active drakes court only those hens which are ready for courtship, ignoring the physiological 'wallflowers' . . . ." "I have seen Canvasback drakes ignore passing bands of paired Canvasbacks, but join a prenuptial courting party." Territory for river ducks must include water, a loafing spot (one or more), nesting cover (adjacent or nearby), and food. Experiments are cited to demonstrate the need of loafing spots appropriate to each species.

There is emphasis on the need by ducks for suitable environment and cover in which to pass the flightless stage of wing molt (3 to 4 weeks in captive canvasbacks). The canvas-

backs, redheads, and lesser scaups resort to small lakes whereas river ducks use marshes for this period. "The tules swarm with such drakes and the Phragmites beds rattle like a wicker shop with hiding birds." On July 25, 1940, over 300, mostly mallards, baldpates, and pintails, were flushed from one tule island of less than a quarter acre. The uneven sex ratio of fewer females may trace in part to the later molt by this sex when such cover is lessened by seasonal drought, making them more vulnerable to predation or to botulism.

The terminal chapter contains sound philosophical meat for every wildlife biologist and game administrator. The Delta Marsh studies and pertinent observations elsewhere are brought together for critical examination of the seasonal and other factors influencing the supply of shootable ducks. The sex ratios at various times of year, the roles of mated and unmated birds in the courting season, the needs for territory, brood production, the problems of summer censuses, and the post-breeding and shooting periods all are reviewed, but "There are many questions, all vitally important, still unanswered."

The author has demonstrated his ability in ornithological research and its interpretation for practical use; he has a sprightly literary style that holds the reader's attention; and he has the artistic still to record effectively, in pen-and-ink sketches, the often transient features of posture and behavior of his subjects, as an aid to interpreting the textual account.—TRACY I. STORER.

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